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# OCCURRENCE AND EFFECTS OF HIGH TEMPERATURES ON RATIONS STORED IN CONTAINER VANS AT YUMA, AZ, 1992-1995

by

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**13. ABSTRACT** *(Maximum 200 words)*

Three container vans (CVs) used to transport and store rations in Operation Desert Shield/Storm (ODS) in 1991 were relocated at the Yuma Proving Ground, Yuma, AZ to monitor heat stress occurring in military rations in a desert climate. One of the vans contained Meal-Ready-To-Eat (MRE) Rations, one B Rations and one contained Tray Rations. A total of 64 thermocouples were attached throughout the vans and temperatures were recorded hourly. Time-temperature indicators (TTI) were also attached to some cartons, and sample MREs inserted for sensory and objective evaluation after storage. Temperatures were analyzed for the period 18 June 1992 to 31 December 1995. Results show that despite the small headspace in the CVs, the maximum temperatures in the most critical top ration cases rarely exceeded 120 °F (49 °C), although temperatures four inches below the roof reached 151 °F (66 °C). Rations stored for the summer six months in the vans experienced about the same heat stress similar rations stored at a constant temperature of 100 °F. Temperature dependence of sensory and objective degradation of rations stored in the vans was consistent with an Arrhenius activation energy of 26 kcal/mole. Effective mean constant temperatures computed to represent the degradation caused by the varying van storage temperatures in 1995 were 93 °F for the year, 100 °F for the hottest summer six months, 106 °F for the hottest three months, and 108 °F for the hottest month. For periods of less than one year, the seasonal effects are extreme, the hottest summer month experiencing about 40 times the degradation rate of the coldest winter month. An external solar shield tested during 1995 reduced the most critical case air temperature by about five °F, resulting in a projected 50% increase in shelf life at the activation energy stated above. Internal
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insulation reduced maximum case air temperatures by 5-11 °F but reduced mean only 1-3 °F. Linear correlation of weekly and monthly mean storage vs ambient air temperatures was high, permitting prediction of storage stress from readily available climatic data. Since the mean and maximum temperature data are similar for all three vans, with very different construction and loads, they can safely be assumed to apply to most CV heat stress situations for military rations. They also are highly comparable to the similar data for boxcars and storage dumps obtained over 40 years ago in the same location.

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# PREFACE

# OCCURRENCE OF HIGH-TEMPERATURE STRESS IN RATIONS STORED THREE YEARS IN CONTAINER VANS

## I. Introduction

**a. Objective.** This report summarizes the results of a study of high temperature stress in military rations stored at Yuma Proving Ground (YPG), Yuma, Arizona in so-called Container Vans (CVs), currently used as the major mode of ration transport and field storage in the military. The vans were instrumented with thermocouples in June 1992 and a technical report was written on the temperature data and the effects of temperature during the summer of 1992 (Porter et al., 1). This current report summarizes temperature data obtained through 1995, effects on rations stored in the vans, and the effectiveness of a solar shield erected over one van in the summer of 1995. However, this report has also included introductory material, figures, tables, and findings from the initial report, as needed to make this a complete final report.

**b. Background.** Currently prescribed high-temperature testing regimes for military rations were developed 40 years ago, based on dump, boxcar and warehouse storage studies conducted by Porter et al. (2,3,4) and reported areas of weather extremes around the world (Riordan, 5). Extensive reports on high temperatures in storage spaces are contained in Krause (6). During Operation Desert Storm/Shield (ODS) in 1991, it became apparent that rations were not usually transported or stored in these modes, but in somewhat standardized commercial CVs, adaptable by ready transfer to truck, rail, shipboard and desert field storage locations. The boxcars studied earlier can be loaded with rations only to a height five feet below the roof and have wooden side wall insulation between the metal outer surface and the ration pallets. In contrast, due to the configuration of the door, the newer CVs can be loaded within one foot of the uninsulated steel roof. They also have no wooden side wall insulation. Since temperatures had reached 151 °F (66 °C) six inches from the roof in boxcars, the new CVs appeared to pose a much greater potential thermal stress. In addition, because the CVs are used on truck, rail, shipboard, and often at site, rations may be stored in the CVs for relatively long periods of time, i.e., six months or longer (Norman and Gaither, 7).

A previous publication, Natick Technical Report NATICK/TR-93/027, by Porter et al. in April 1993 (1) summarized the findings from the summer of 1992. The study found that, although the temperatures four inches below the roof reached 142-151 °F (61-66 °C) the maximum temperatures in the top cases of rations rarely exceeded 120 °F (49 °C). Mean temperatures of the air in the top cases of rations were five to seven degrees higher than the outside mean, and there appeared to be a strong linear correlation between mean weekly ambient air temperatures and top case air temperature. This study indicated that ration storage temperatures would probably not exceed temperatures of 120 °F under most climatic conditions around the globe.

**c. Yuma climate and its analogy to areas of worldwide extreme high temperature stress.** The Yuma Proving Ground is a very large area of hot desert, at 32°40' north latitude and an altitude of 206 feet mean sea level (at headquarters). Earlier studies (Corps of Engineers, 8) showed that the Yuma climate is closely analogous to that of other extreme hot-dry areas worldwide (Figures

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1-6), particularly the Middle East, northern Africa and northern India. Yuma has a latitude, Mediterranean winter cloudiness, and wind speed regime similar to the Middle East and northern Africa, so that the solar radiation load is very similar. The diurnal cycle of insolation and hence soil and ambient air temperature are very similar from day to day in hot-dry areas, and the daily and yearly temperature marches are regular and repetitious. Therefore, knowledge of storage temperature regimes permits prediction and generalization to many hot-dry areas of the world, providing the induced temperature response of the storage mode is known.

**d. Procurement of CVs.** Excess commercial CVs used in ODS became available to valid consumers and users in late 1991. Through the Troop Support Division, Office of the Deputy Chief of Staff for Logistics, and the Military Traffic Management Command, three commercial CVs containing, respectively, B rations (B), Meal-Ready-to-Eat (MRE), and Tray Pack (T) rations were procured. The vans were shipped to Yuma from Oakland Depot, California, where they had been stored after return from Saudi Arabia. Funding for installing temperature recording equipment, downloading of data, and data analyses was obtained from research funds available for ODS-related issues.

**e. History of CVs.** The history of the CVs and their contents during 1991 is largely unknown. It is known that the rations were shipped from the U.S. by sea (approximately one month) to Saudi Arabia soon after January or February 1991 when the rations were produced. During the conflict they were stored in an unknown manner, but presumably in CVs on desert sand, either alone or as part of a vertical stack of vans, which was customary (and which is a much cooler environment for the vans below the topmost one). The vans were shipped back by sea by November 1991, having endured a desert summer. After extensive negotiation by Natick personnel, the vans containing the rations were transported to YPG, where they remain as an available heat stress laboratory for ration storage.

**f. Findings.** The results in this report concern the thermal stress on rations stored at YPG, the temperatures reached at various locations in the vans, as well as the outside ambient temperatures throughout the yearly cycles of 1994 and 1995. Some data and analysis from the 1992-93 period are also included. The report also documents the effects of erecting a solar shield over one van in the summer of 1995.

## II. Research Methods

**a. Site and situation.** The three CVs were sited (Figure 7) at the Material Test Area of YPG, at an elevation of 350 feet on a large alluvial fan sloping from Castle Dome Mountain about 25 miles north of Yuma, AZ and three miles east of the extensive spillways and impounded water areas of the Imperial and Laguna Dams. The site is in the southwest corner of the U.S. and has one of its most extreme hot-dry conditions.

**b. Location and orientation of vans.** The vans were placed 20 feet apart in a lengthwise line oriented 120°-300° from true north, and 500 feet from any large building (Figure 8). They were set with their bottom steel members flush with the desert surface, and from northwest to southeast

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were: B ration van, MRE van and T ration van (Figure 9). Doors of the vans were on the northwest end. There is a line of parked, camouflaged vehicles 60 feet south. The surface is light desert sand plain with numerous small rock fragments having a dark wind-derived patina characteristic of the desert. Albedo of such a surface at Blythe, CA has been determined to be 25%, as compared to 6% for black tarpaulin material. The Yuma Meteorological Team main observing station is less than 1000 feet southwest, affording abundant confirmatory observations of ambient air temperature as well as soil surface temperature, 45° and horizontal surface solar radiation, dewpoint, windspeed and direction.

   c. **Characteristics of vans.** Tables 1, 2, and 3 show salient features of the vans and their loads.

   d. **Insulation.** In each van, rations were stacked, as received, two pallets high. One-half of the pallets were left uncovered, as received, except for the installation of thermocouples. Over one-fourth of the pallets, one layer of empty ration cases (closed) was placed on top for insulation. In the remaining fourth of the van, one inch of rigid foam insulation, foil faced on both sides, was placed on top of the pallets for insulating purposes.

   e. **Solar shield.** On 2 May, 1995, a 50' x 50' Ammunition Solar Cover, or solar shield, was erected over the T ration van (Figure 10). The shields are being developed by the Shelters Division of the Sustainability Directorate at Natick. The cover used is a preproduction prototype, which should reflect approximately 50% of the solar load. The shield was erected by staking the opposite sides of the cover approximately 39 feet apart, supported by two rows of columns 16.5 feet apart. This resulted in an isosceles triangular prism shape with the height of the cover approximately 12 ft.

   f. **Measurement procedures.** Thermocouples were placed in a total of 64 locations in the three CVs and outside air. Temperatures were measured and recorded on an hourly basis using the T-type thermocouples, 2 in a shelter in the outside air, 38 in the MRE van (Figure 11), and 12 in each of the B (Figure 12) and T (Figure 13) vans. All temperatures in this report are stated in degrees Fahrenheit.

   g. **Ambient air temperature measurement.** During the first year (1992-1993), ambient air temperature was recorded by two thermocouples 4" apart suspended 9" above the bottom of a white wooden shelter 9" wide, 6 ½" deep and 16" high (Figure 14). There was a 4" hole in the floor of the shelter, the bottom of which was 4' above the desert surface, 23' northeast of the center of the MRE van and 18'8" southeast of the northeastward projection of its northwest end. There were also about 10 small (1/4") holes in the east and west faces of the shelter. A black solar energy collector panel (13"x13") was located on the roof of the shelter, in order to recharge the Campbell Micrologger data recorder. The two thermocouples gave very similar readings throughout summer 1992, but it was felt that the setup was not a perfect replica of a standard Weather Bureau Instrument Shelter, as evidenced by the fact that ambient temperature in the shelter was three degrees higher at maximum than that measured at the Yuma Meteorological Team standard shelter 1000' southwest. To check on possible heat gain from the solar energy collector, a standard thermocouple probe in an approved reflective metal shield (nested hemispheres) was installed 5

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February 1993 and all subsequent ambient air temperature readings were drawn from this site. This probe was located approximately 25 feet northeast of the center of the MRE van.

**h. Case air temperature measurements.** Thermocouples for measuring case air temperatures were installed inside the case, on the surface and near the top of the ration package, whether the outer plastic meal bag for the MRE or the metal container of the B and T rations. This is shown in Figure 15. Data obtained in previous studies in boxcars from simultaneous thermocouple measurements in case air and food showed no significant difference between the two (Porter et al., 2).

**i. Data recording.** Reading and storage of the data was by a Campbell Micrologger located next to the north face of the MRE van 9' east of its west end. Temperature calibration was by isopoint reference and time was checked periodically for any drift occasioned by the heat. Data were downloaded weekly onto disk and forwarded to Natick for analyses.

**j. Data analyzed.** The data analyzed for this report primarily include the 12-month data from 1994 and the 12-month data from 1995, although data and analyses from 1992 and 1993 are included when considered important for the interpretation of later data.

The configuration of the ration pallets, with insulation, is shown in Figures 16 and 17. A list of the reported positions is shown in Table 4, together with their thermocouple number, by which they are reported in later graphs and tables. This report focuses on the data from an outside ambient temperature thermocouple (thermocouple 2) and 21 thermocouples located in the three vans. The cases monitored were the surface cases on the south side, considered the most extreme exposure. The readings in the B ration van are represented by thermcouples 4-13, T ration van thermocouples 16-25 and MRE ration van thermocouples 28-37. For each van there is a thermocouple representing the roof air temperature 4" below the roof (thermocouples 4, 16, and 28), uninsulated locations in the southwest corner of the vans in the top row of cases (thermocouples 5, 17, 29) and uninsulated locations in the middle of the vans in the top row (thermocouples 7, 19, 31) and in the row below it (numbers 8, 20, 32). The top rows with empty cases for insulation in the middle of the van are represented by thermocouples 9, 21, and 33. The Styrofoam©-insulated sections are represented by thermocouples 11, 23, and 35 (top case in a middle section) and 13, 25, and 37 (top cases in the southeast corner).

**k. Measurement of effects of high temperature storage on ration components.** A number of MRE X rations were substituted for cases in the top layer, first or second rows of the south corner of the MRE van on June 25, 1992 and some were returned to Natick for sensory and colorimeter evaluations after storage for a summer at YPG (September 25, 1992) as detailed in the earlier technical report (Porter et al., 1). Additional cases of these rations were subjected to colorimeter measurements and evaluated for sensory attributes after one year, two and three years of storage at YPG (Study No.1). They were returned to Natick where they were evaluated with samples stored at Natick at 40 °F during the same period. To validate the sensory and colorimetric data thus obtained, a similar insertion of MRE XII rations was carried out on July 28, 1993. Withdrawals were made at three, six and nine months and after one, two and three years of storage.

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The samples stored simultaneously at YPG and at Natick allow a comparison of the effects of storage in CVs in a variable high heat stress environment with those in constant temperature storage (Study No. 2).

The sensory evaluations were conducted on five shelf-stable MRE items, applesauce, cheese spread, grape jelly, peanut butter, and escalloped potatoes with ham. These products were also studied in a research effort to evaluate items in long-term storage (three years) at 40 °F and 80 °F with items stored at higher temperatures (100 °F, 120 °F, and 140 °F) for as long as the quality level permitted. The evaluations were conducted by a panel of food technologists who used attribute rating scales specifically developed for the products. The attributes included color, viscosity, degrees of sweetness and degrees of sourness, which were rated on nine-point intensity scales. In most cases these rating scales described the magnitude of an attribute, such as "very sweet" to "very low sweet" or were descriptive, i.e., "light cream color" to "dark yellow brown color." Panel members also rated the overall quality on a rating scale in which a score of one corresponded to "extremely poor", five referred to "neither good nor bad" and nine corresponded to "excellent."

Color readings to measure L*a*b* values were taken prior to sensory evaluations using a portable colorimeter (Hunter MiniScan Model MS/S). manufactured by Hunter Associates Laboratory, Inc. of Reston VA. To measure the color, the colorimeter was first standardized using the standard white tile. The applesauce, grape jelly, peanut butter, or cheese spread was filled in a 6.4 cm glass sample cup and covered with an opaque cover. The colorimeter was inverted, the glass cup placed on the lens, and the color values read through the bottom of the glass surface. The escalloped potatoes with ham were read similarly, except that the samples were pureed in a blender prior to filling the cups.

The 12 entrees in the MRE X or XII were also evaluated by technical panels for appearance, odor, flavor, texture and overall quality after one, two, and three years of storage in the MRE container van at Yuma and evaluated with similar samples stored at 40°F. Appendix C contains the evaluation sheets used for these studies.

**l. Calculations of effective mean temperatures.** Many products, including food, will experience deleterious changes on storage and the rate of these changes in most, but not all cases, is accelerated at higher storage temperatures. Because this is an exponential increase, in calculating the cumulative effect of storage temperatures fluctuating in response to changing ambient conditions, more weight is given to the higher storage temperatures. Therefore the mean effects of varying storage temperatures are greater than would be predicted from their arithmetic mean. The temperature corresponding to the weighted mean rate, derived by logarithmic averaging using either the Arrhenius equation or the Q10 approximation (Labuza, 9) is termed the effective mean temperature (Hicks, 10). The constant that defines the rate increase with temperature rise is called the activation energy ($E_a$), which is dependent on the chemical reactions causing the change. Such reactions could be, for example, Maillard browning, lipid oxidation, vitamin degradation, or a textural change. Because most foods have such a large array of reactions occurring simultaneously, it is difficult to establish a single activation energy. Thus, the sensory studies of components stored in the vans at Yuma were used to set an appropriate activation energy to replicate the degradation found in MRE rations upon storage.

Effective mean temperatures were calculated by computer for 1995 for the temperatures derived from the thermocouples listed in Table 4, using the Arrhenius equation and an assumption of zero order kinetics (Labuza, 9). The latter is approximately valid for the early stages of degradation. An activation energy of 26,000 cal/mole was selected because of its observed approximate correlation to known ration shelf life and its use in time-temperature indicator labels (TTI). It corresponds to a Q10 of about four (fourfold increase in reaction rate with a 10 degree C rise in temperature), the temperature dependence of the Maillard browning reaction, one of the most temperature sensitive. The mean of all hourly rates during a period computed by the Arrhenius formula corresponds to the constant temperature of storage that will best duplicate the rate of quality degradation produced by storage at the varying temperatures used in its computation, using the appropriate $E_a$. The calculation of the relative rate employs the Arrhenius formula as follows:

$$k = k_o e^{-E_a/RT}$$

where k is rate at temperature T, $k_o$ is the rate at a given reference temperature, $E_a$ is the activation energy in calories per mole, R is the gas constant in cal/degree/mol and T is the absolute temperature in Kelvin. Relative rates are computed for each of a series of temperatures, the rates averaged and the temperature corresponding to the average rate is computed. The 80 °F reference temperature was selected because it is used as the norm for ration storage, i. e., rations must withstand storage for three years at 80 °F.

**m. Time-Temperature Indicator (TTI) Labels.** TTI labels are indicators that can integrate time and the effect of temperature on rate at specific activation energies and thus can be used as indicators of the actual heat stress the products have experienced. In 1992, when the vans were instrumented with thermocouples, bar-coded TTI labels manufactured by LifeLines, Inc. of Morris Plains, New Jersey, were placed on representative cases of rations in various locations and were monitored periodically. These labels were based on a substituted diacetylene monitor that initially is white and eventually becomes bluish and purplish upon polymerization (private communication, LifeLines, Inc. (11)). The changes in the TTI labels were monitored by measuring the optical reflectance of the bar coded labels with a scanner. Reflectance decreased with increasing time and temperatures of storage, decreasing more quickly with higher temperatures. Results of these studies can be found in the earlier report (1).

A TTI label is now available from LifeLines, Inc., which can be monitored visually as well as instrumentally. These labels (Figure 18) sometimes termed Bull's Eye labels, are being used to monitor MREs in storage throughout the world. The labels have an inner circle which darkens with time and temperature, darkening more quickly at higher temperatures. A dark outer ring is used as a reference. Based on extensive storage studies of rations stored at constant temperatures at Natick as well as experience with rations stored under ambient conditions throughout the world, Natick projected that an activation energy of 26,000 cal/mole would be suitable for a TTI, to be used in monitoring the heat stress on MRE rations. LifeLines, Inc. developed and produced a TTI with this activation energy. As produced, the center of the Bull's Eye label is much lighter than the

outer reference ring. With time and temperature of storage the inner disk darkens, eventually becoming darker than the reference ring.

The diagonal line in Figure 28 illustrates the time at which the inner disk of the TTI will match the outer reference ring. Thus the inner disk is as dark as the outer reference ring after approximately 1000 days (2.7 years) of storage at 80 °F (27 °C), 200 days (6.6 months) at 100 °F (38 °C), and 40 days at 120 °F (49 °C). The sensory data from the MRE rations stored in the CVs at Yuma were used to validate the chosen activation energy (26,000 cal/mole) of the TTI labels used to monitor MREs in storage. Since many degradation processes are going on, it is realized that any activation energy represents a compromise. The chosen figure represents a relatively extreme response to temperature, which is expected to cover most storage experience.

## III. Results

### a. Hottest days 1992-1995

**(1) Storage and ambient temperatures on the most critical days of 1992 and 1993.** The first YPG report (1) showed that the hottest day of 1992 occurred on August 16 with a maximum ambient temperature of 117 °F (47 °C). The hottest day of 1993 occurred on August 1, when the maximum temperature reached 119 °F (48 °C). Table 5 and Figure 19 show the temperatures occurring outside the vans and selected thermocouples inside the three vans on August 16, 1992 and August 1, 1993. Included are the air 4" below the roof and air in the top southernmost cases of rows 1 and 3. In 1993 and thereafter, channel 2 (which, as stated above, had been relocated in a shield of nested hemispheres) was used for the ambient air reading because channel 1 had some missing data points in the summer of 1993 and was not considered optimally shielded. At first glance, it would appear that 1992 and 1993 are not too dissimilar except that the hottest day of 1993 was not quite as hot as that of 1992. Upon graphing the data, however (Figure 19), it is obvious that the temperature changes in 1993 were different.

Table 6 shows the hourly changes from five thermocouples between 1000 hours and 1300 hours in 1993. Between 1100 and 1200 hours the roof air temperature decreased by 12.2 °F in the MRE van, by 15.4 °F in the B ration van and by 8.6 °F in the Tray ration van. During this time, the outside ambient air decreased only by 1.8 °F degrees, while the inside top carton air of the MRE van showed only a 1.2 °F increase. It was determined from the climatological data that a decrease in solar radiation due to cloud cover occurred during this time. The decrease in solar load reduced the roof air temperature significantly more than it decreased the ambient air temperature. Since radiation from the roof and walls is the major determinant of case air temperature, this finding led to the installation of a solar shield over the Tray ration van in May 1995.

**(2) Storage and ambient temperatures on the most critical days 1994 and 1995.** The data from the hottest days of 1994 and 1995 are found in Figure 20. Tables 7, 8, and 9 summarize the mean, standard deviation, and absolute maximum temperatures on the hottest days each year from 1992 to 1995. On only two days from 1992 to 1995 did temperatures in any of the vans in the most critical cases exceed 120 °F. Two of these values were 122 °F (50 °C) in 1992 and 1995 in

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the top corner case in the B van, an insulated case, and therefore somewhat suspect. The middle top case of the T van, uninsulated, also reached this figure in 1992, again somewhat suspect when checked with simultaneous values at other positions.

**(3) Influence of insulation on top case air temperatures.**   Figure 21 illustrates the effectiveness of the insulation and the empty cases on the hottest days of 1994 and 1995 for the top carton cases in the MRE van.  Tables 10 and 11 show these effects in more detail for all three vans for both the middle and the corner top cases on the two hottest days of 1993.  The data from the B van are difficult to analyze because of a few apparently defective thermocouples.  In Table 5 (Hottest Days, 1992-1993)  the 1992 data from thermocouple number 19 of the T ration was footnoted as being possibly defective due to the high standard deviation and the data were not included in Figure 19 (Hottest Days, 1992-1993). The high standard deviations have not been found in subsequent years.  However, when the vans were being dismantled in 1996, thermocouple number 13 (top corner, insulated location in the B ration van) was not in its intended location, so the data from this thermocouple are suspect.

Figure 21 and Tables 10 and 11 show that on the hottest days, case air maximum temperature is reduced by 5 to as much as 11 °F although the minimum is little changed.  Means are therefore reduced only 1-3 °F.  The reduction is greater in the middle than the corner cases.  Empty cases have about the same effect as the insulation. Therefore, in assessing the impact of the insulation, one must also consider that, although it aids in decreasing daily maximum storage temperatures, it also retards cooling to some extent at night.  If insulation is to be used, placing empty cases on top of the cases of rations is as effective as adding prefabricated insulation.  When cases of rations are emptied due to use of the rations in the field, the empty cases could simply be placed back in the vans.

**(4)  Effect of solar shield on the T ration van on the hottest day 1995.**  The solar shield erected over the T ration van (Figure 10) lowered the roof air temperature to that of the outside ambient air.  The effects on the top case air are somewhat less dramatic.  Figure 22  depicts the hourly march of the top case air temperatures at the R3 position (uninsulated in the middle of the van) for the three vans on the hottest days in both 1994 and 1995.  This shows that the T ration van had the highest maximum temperature in 1994 but not in 1995.  Before the erection of the solar shield, the data from the top case air thermocouple in the T ration van has shown greater temperature swings (larger standard deviations and higher maximum temperatures) than similar thermocouples in the other vans and so the effectiveness of the solar shield should not be based solely on the data from this thermocouple.  Table 12 shows the maximum temperature and the changes in maximum temperature of major locations in the three ration vans from 1995 when the T ration van had the solar shield and when none of the vans was shielded.  The data from columns for 1994 and 1995 in Table 7 (Mean Temperatures, Hottest Days) show the decrement in mean temperature produced by the solar shield over the T ration van on the hottest days.  From these data and considering the 1-2 degree increase in mean and maximum temperature at comparable positions in the unshielded vans between 1994 and 1995, it can be predicted that the shield will produce a four-to-five degree drop in mean case air temperature and a six-to-seven degree drop in maximum temperature at the most vulnerable, uninsulated positions on the hottest days.

**b. Monthly and yearly temperature data, 1994 and 1995.** Appendix A summarizes these data for 1995, including the mean temperatures, standard deviation of the mean temperatures, the absolute maximum and minimum temperatures, the mean maximum and minimum temperatures and the ranges between absolute maximum and minimum and between the mean maximum and mean minimum temperatures. The number of data points listed verifies the number of data points for each month. This correlation is a check on any missing data, such as occurred in January for thermocouple number 21. Similar data are found in Appendix B for 1994, however the mean maximum and mean minimum temperatures were not calculated for 1994.

**c. Prediction of storage air from ambient air temperature monthly means.** Figure 23 shows the monthly mean temperatures in top middle case and ambient air for the MRE van in 1992-93. The two differ in the winter by about 5-1/2 °F and in summer by nearly 11 °F. Figure 24 is a plot of top middle case versus ambient air to illustrate the nearly linear relation between storage and ambient air temperature monthly means. Tables 13 and 14 show the linear regression analyses for 1992-93 and 1995 monthly mean data. It is clear from the very high correlation coefficients that for a solar controlled hot-dry climate, as was found in boxcars and storage dumps (Porter et al., 2, 3), prediction of storage air temperatures from readily available monthly climatic ambient temperature means is readily possible.

**d. Effect of the solar shield on yearly temperature data.** Figure 25 shows the monthly mean temperatures for the top case air temperature (Position R3, Uninsulated, Middle of CV) for the three vans in 1994 and 1995. It shows that for this location the mean temperatures for all three vans were very similar in 1994, but in 1995 the mean temperature for the T ration van with the solar shield was significantly lower than the other two vans. For the eight-month period (May to December 1995), the mean temperature of this location was 90.0°F (32 °C) for the MRE van, 91.1° (33 °C) for the B ration van, and 86.1° (30 °C) for the T ration van. Therefore, the solar shield reduced the mean temperature of the top carton air from four to five degrees. This is consistent with findings from other thermocouples. Figure 26 shows the monthly mean maximum and minimum temperatures for the same position for 1995. It shows that the solar shield was effective in reducing the maximum case air temperatures of the van but had little effect on the minimum temperatures.

**e. Effective mean temperatures for 1992-93 and 1995.** Details of temperature data for 1995 are shown in Appendix A and for 1994 in Appendix B. The monthly effective mean temperatures for 1995 at an activation energy of 26,000 cal/mole are shown in Appendix Table A-2 and for 1992-93 in Figure 27 (calculated for both lipid oxidation, 12,700 kcal and Maillard browning, 25,400 kcal). As Figure 27 shows, the monthly effective mean temperatures of the top case air usually differ from their arithmetic means by only plus one to two degrees (the effective mean temperature increment). With the high mass of food in the vans there are relatively low monthly temperature fluctuations (Table A-3 and B-2) and therefore a low effective mean temperature increment. Thus for many purposes the monthly mean case air temperatures are adequate to use when assessing the monthly effective mean temperatures. The yearly effective mean case air temperature is obtained by effective averaging of the monthly effective means (or, with little error, their arithmetic means) and produces a much greater increment because of the wide yearly range.

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The effective yearly means, together with the monthly arithmetic and effective mean temperatures may be found in Table 15 and Appendix A, Tables A-1 and A-2. The yearly effective means for most of the ration cases are generally seven to nine degrees higher than the annual arithmetic mean temperatures.

**f. Effective temperature contrasts between summer and winter.** For periods of less than one year, the seasonal effects are extreme. As shown in Table 15, the hottest summer month experiences about 40 times the degradation rate as the coolest winter month, the hottest three months about 20 times and the hottest six months about eight times its winter counterpart. For the most extreme year, 1995, and an activation energy of 26 kcal/mole, the yearly effective mean temperature in the top middle (most critical) case is 92.7 °F (33 °C); worst summer six months, 100.2 °F (38 °C); summer three months, 105.6 °F (41 °C); and summer month, 108.0 °F (42 °C). These constant storage temperatures will duplicate the Yuma container van storage experience and, in the light of Figure 25, will be nearly the same for the other two vans, of different construction and load. The current requirement of six months at 100 °F is clearly validated. Shelf life, the inverse of rate, obviously depends on season of entry into storage, unless the period is several years.

**g. Increase in shelf life with solar shield over the T ration van.** Figure 28 is the graph produced by LifeLines Technology, Inc. (11) showing the anticipated shelf life of rations at various temperatures. The shelf life anticipated at five degree intervals from 80°F to 100°F is shown in Table 16.

This table shows that the shelf life of MREs can be increased by approximately 50 percent with a five degree decrease in mean temperature through the use of a solar cover. Economic considerations are being evaluated to determine if this is a cost effective approach to increasing the shelf life of rations in high-heat environments.

**h. Evaluation of rations.** The sensory portion of this study is a follow up of a separate study examining the effects of storing five MRE components and one Ration Cold Weather component at constant temperatures of 40, 80, 100, 120 and 140 °F for up to a three-year period. The details of the constant temperature storage study are being addressed in a separate report. The effects of storage at artificially created, short-term cyclical fluctuating temperatures have also been recently studied (Shaw et al., 12). Samples of MRE ration components that arrived in the van were evaluated informally at YPG at the time of installation of thermocouples. Although the components showed evidence of high temperature storage (principally Maillard browning reactions), only the chocolate-covered cookie, which had melting of the chocolate coating, was obviously not acceptable. As expected, with time the rations that came inside the vans became more heat stressed. When the vans were emptied in September, 1996, some cans were leaking, primarily the ones containing canned fruits, such as peaches, pineapple and pears.

Table 17 lists the technical panel evaluation of entrees from newly procured rations inserted in the vans and removed after one, two and three years of storage. Of the 12 products evaluated, four did not show any statistically significant differences in overall quality ratings from the samples stored at 40°F at any of the three year intervals. Four of the 12 rated significantly lower in overall

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quality after one year of storage, two additional entrees were significantly lower after two years and two were only significantly lower in overall quality ratings after storage for three years at Yuma. This indicates relatively good shelf stability of the MRE entrees, particularly with the elimination of the tuna with noodles, omelet with ham, and chicken a la king from future MRE menus.

Figure 29 shows the overall quality ratings of five ration components from study number 1 and study number 2. The tests are similar except that study number 1 began on June 25, 1992, and study number 2 began on July 28, 1993. The products evaluated were made by the same specification but were not from the same lots. Withdrawals for study number 1 were conducted after three months and one, two, and three years of storage. For study number 2, withdrawals were conducted after three, six, and nine months as well as after one, two, and three years of storage.

Found in Figures 30 and 31 are the overall quality ratings of these five components compared with similar ratings from these components stored at constant temperatures from 40 °F to 140 °F. In most cases the ratings fell lower than similar products stored at a constant temperature of 80°F and slightly above the ratings of components stored at 100 °F. The most comparable thermocouple to the location of these inserted rations would be thermocouple 31 (row 3 south, top carton of MRE van) which had a yearly mean temperature of 84 °F in 1995 and 82 °F in 1994. Using the activation energy of 26,000 calories per mole as in the TTI labels, the yearly effective mean temperature for this location would be 93 °F in 1995. Thus the ratings are as might be anticipated for storage in these conditions. These results also validate the use of 26,000 calories per mole for the degradation of MREs during storage in high heat environments. As expected, the summer heat at Yuma is very stressful to stored food products and a very important factor is how many summers the products have experienced.

Certainly some products are much more affected by the storage temperature than other products. Peanut butter, whether stored at constant temperatures at Natick or inside the container vans at Yuma, showed very little effect from the heat.

Figure 32 shows the L* values from applesauce and cheese spread samples from Study Number 1 versus L* values from similar products stored at constant temperatures at Natick. The L* values of samples of cheese spread decrease at the same rate as the samples stored at a constant 100 °F for the first year, decrease more slowly than those at 100 °F at two years, then at a very similar rate to samples at 100 °F at three years. For the applesauce, L* values paralleled the 100 °F storage quite closely over the three month summer storage, then were between the 80 °F and 100 °F values throughout the remaining time period. Figure 33 shows the panel color ratings for Study Number 1. Clearly, the panel was affected strongly by color change, the objective measure of which (Figure 32) showed nowhere near the decrements assigned by the panel in the first three months.

## IV. Conclusions

From the analysis presented here, the following seven conclusions can be drawn:

a. The maximum temperature on the extreme days in unprotected top carton air is, with few exceptions, below 120 °F in all CVs. Realistic ration storage testing, except for exceptional

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exposures in locations such as tanks, airplane cockpits or lifeboat storage, need never exceed this figure.

b. Rations stored for the summer six months in cases in the vans will experience more heat stress than rations stored for the same period at a constant 80 °F but slightly less than those stored at 100 °F. This finding is documented by both sensory panel and objective colorimeter data. The current requirement of six months exposure at 100 °F is validated.

c. The temperature dependence of degradation of rations stored in the vans was consistent with an activation energy of 26,000 calories per mole. Effective mean temperatures may be computed from individual storage temperatures using this figure to duplicate at constant temperature the effects of high heat stress storage at the varying temperatures encountered in the field.

d. Because of the extreme heat stress encountered in the summer months, the number of summers or summer months that rations are stored is critical to their condition.

e. A solar shield decreasing the solar load 50 percent will reduce the monthly mean temperature of rations in cases in the most extreme top rows four to five degrees Fahrenheit. This could extend the shelf life of MREs by 50 percent.

f. Using mean monthly ambient (outside air) temperatures (obtainable for most areas as climatological statistics), reliable predictions of mean monthly food storage temperatures in ration cases may be made for hot-dry, solar controlled climates (which embraces most of the high heat stress areas of the globe). Based on these, effective mean monthly and yearly temperatures can be computed. Because of this dependence on monthly mean temperature, hot-dry stations closer to the equator may experience somewhat greater yearly effective mean temperatures than a moderately high latitude station like Yuma, with cooler winters.

g. Since the data for daily maxima and monthly and yearly means are similar for all three vans, having different construction and greatly different loads, they can safely be assumed to apply to most container van heat-stress situations for military rations. They also are highly comparable to maxima and means encountered for rations in boxcars and storage dumps in the earlier heat stress studies in the same location (Table 18 and Porter et al., 2, 3).

# V. TEXT FIGURES
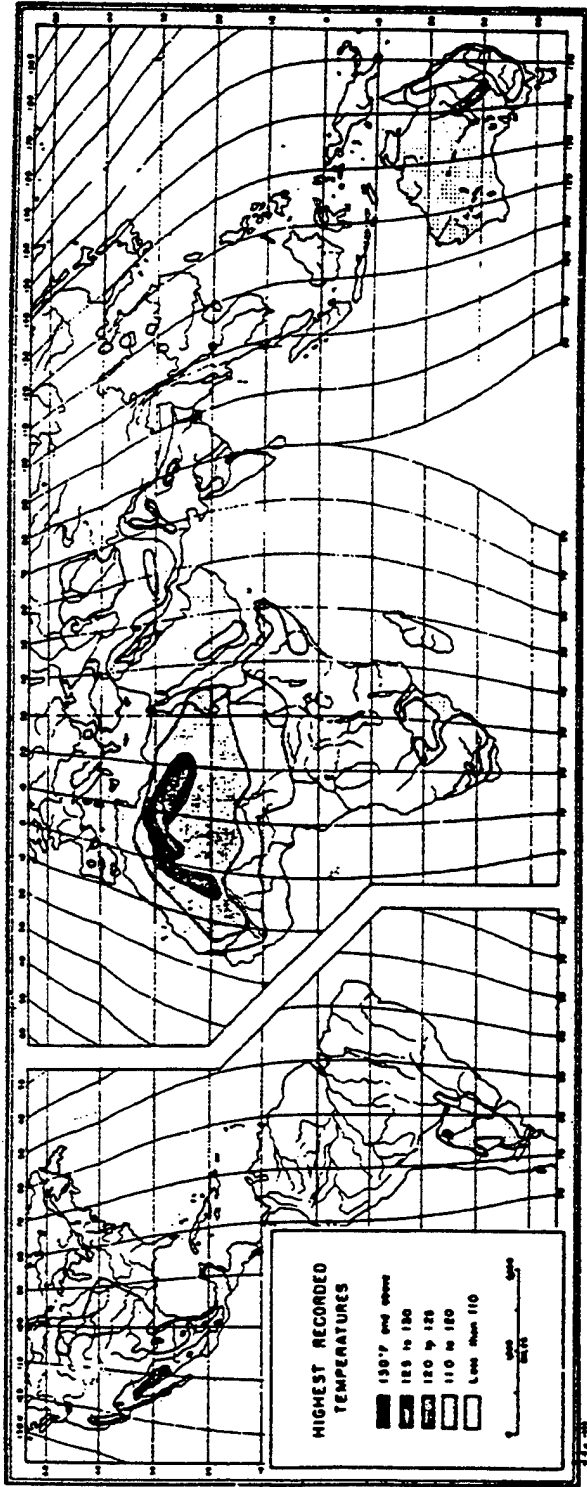
Figure 1.   World's Highest Recorded Temperatures
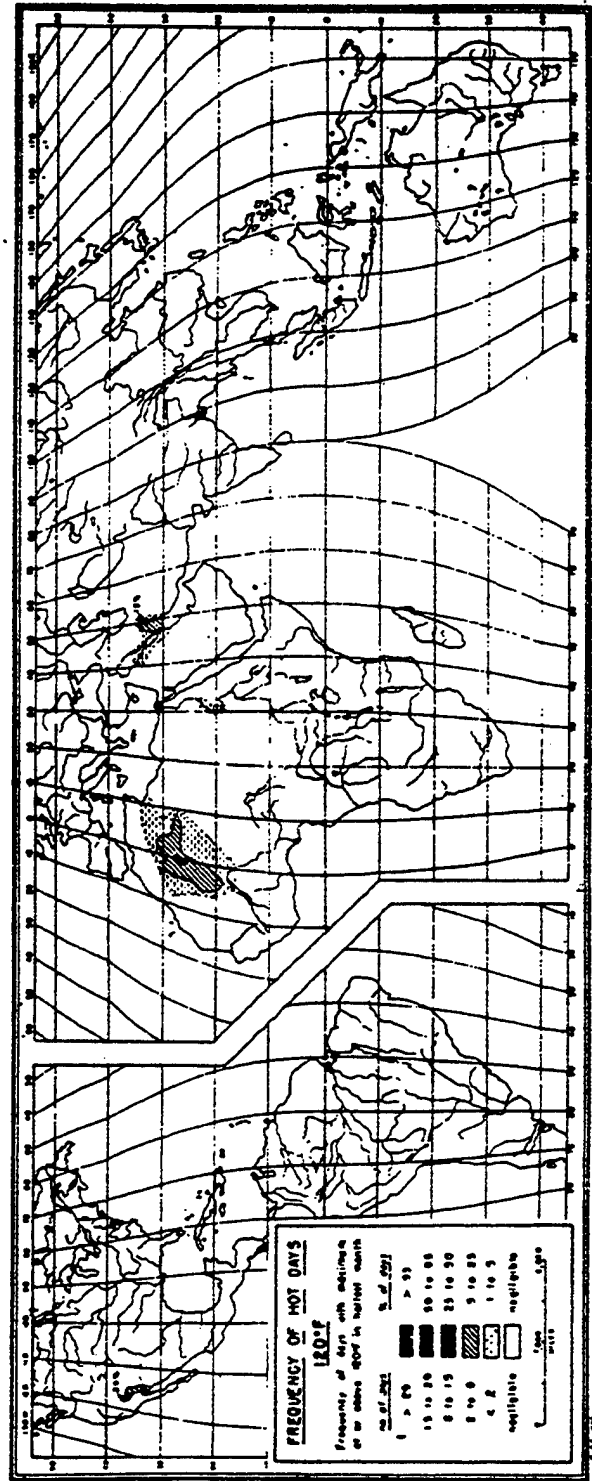


Figure 2.   World's Frequency of Hot Days

Figure 4. Percent of Hourly Temperatures above 85° for June, July, August

White = 0–20%
Gray = 20–40%
Black = >40%

(Based on summary of observations at 102 places 1935–1939.
Compiled from microfilm tabulation of U.S. Weather Bureau,
Environmental Protection Section, Research & Development
Branch, Military Planning Division, Office of the
Quartermaster General, Washington, D.C., June 1951.)



Figure 6. Average Cloudless Day Solar Radiation for July 15 in Langleys per Day

JULY 15
RADIATION VALUES IN ly/DAY
• OBSERVED  ○ COMPUTED



Figure 3. Highest Temperature Expected in 100 Years U.S.A.

White = > 115 deg F
Gray = 100 to 115 deg F
Black = < 100 deg F

(Based on analysis of highest temperatures in each year
1901–1930, at 100 places listed in "Climatic Summary of
the United States" U.S. Weather Bureau Bulletin W, 1930.)



Figure 5. Climatic Average Daily Solar Radiation for July, in Langleys per Day

Figure 7.   U.S. Army Yuma Proving Ground, Mobility Test Area

▲ = Location of container vans
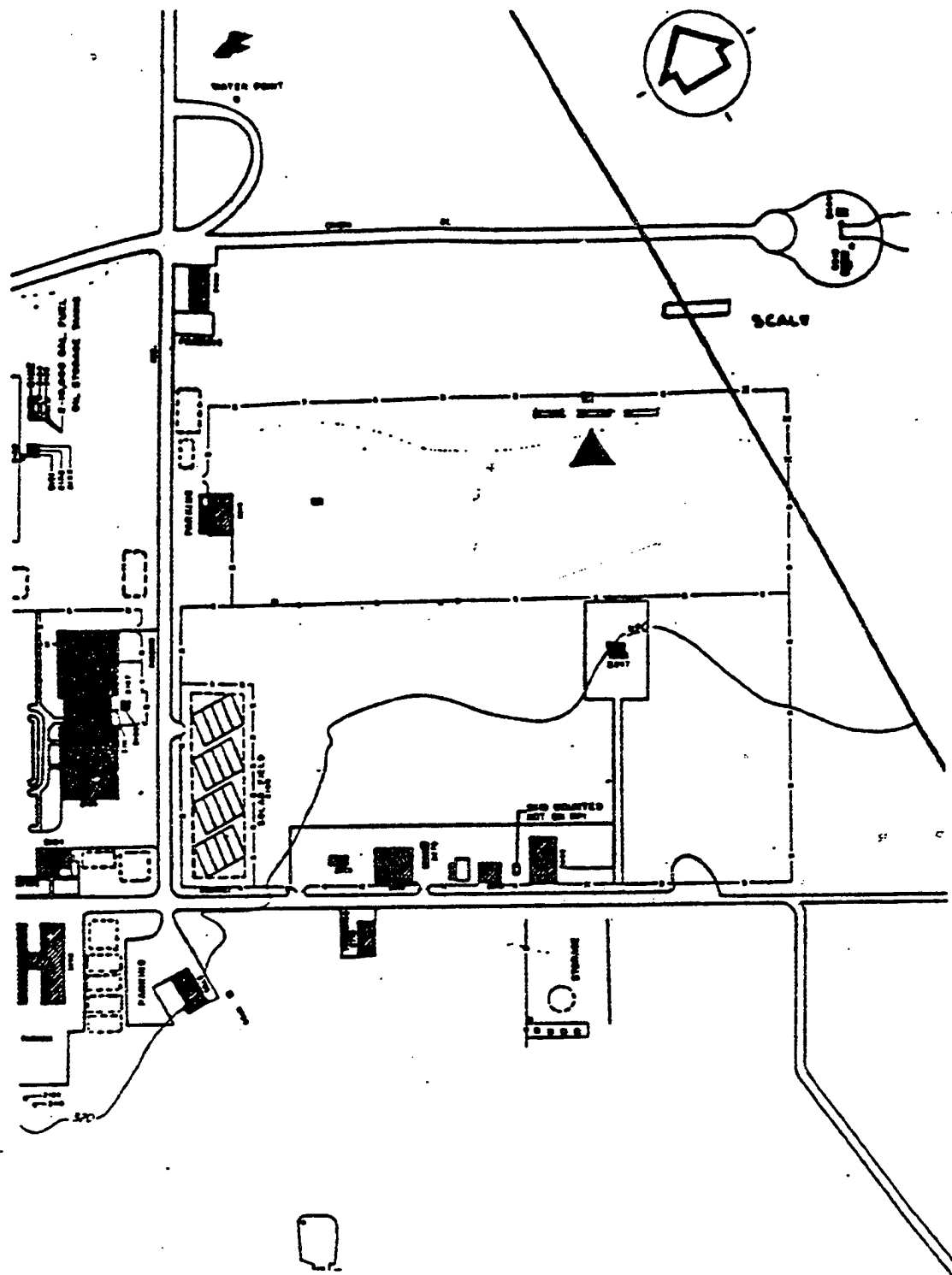
Figure 8.   U.S. Army Yuma Proving Ground, Mobility Test Area
Headquarters/Materiel Test Area

▲ = Location of container vans
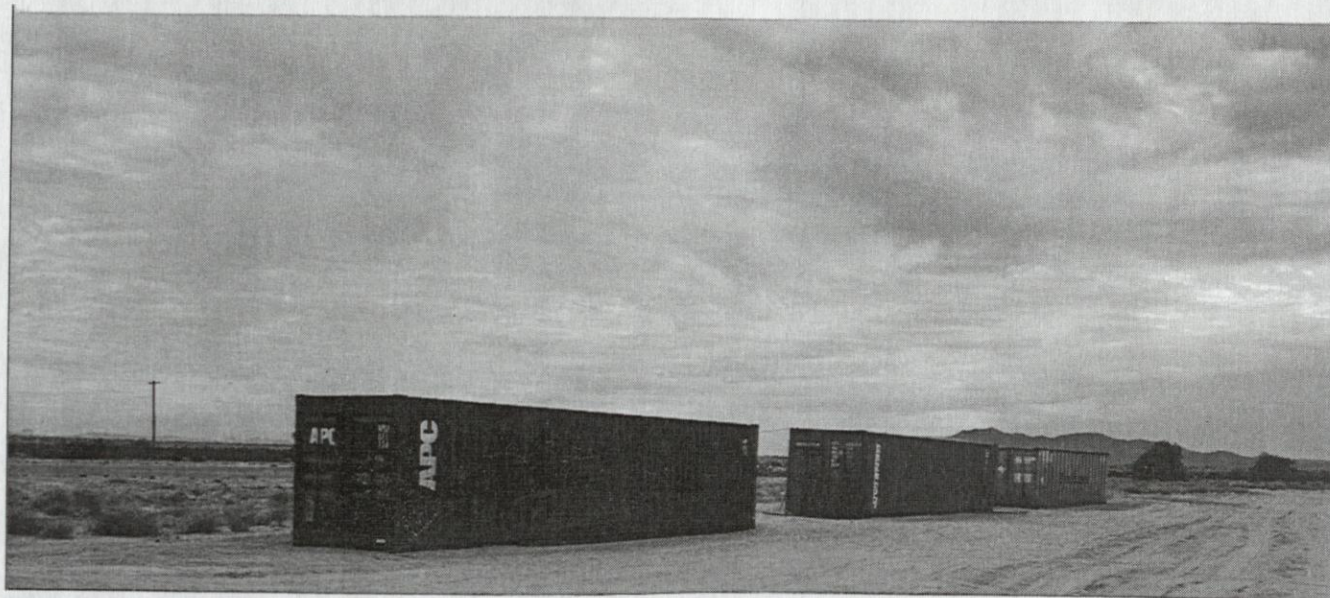
Figure 9. Container Vans for Ration Storage Test at Yuma Proving Ground.
Left to Right: B Ration, MRE, T Ration Storage



Figure 10. T Ration Van with Solar Shield Erected

Figure 11. MRE Storage Container Van with Doors Open and Ration Cases Visible. Dr. and Mrs. Porter Inspect Rations in the 1990s Follow-up of 1950s Study.
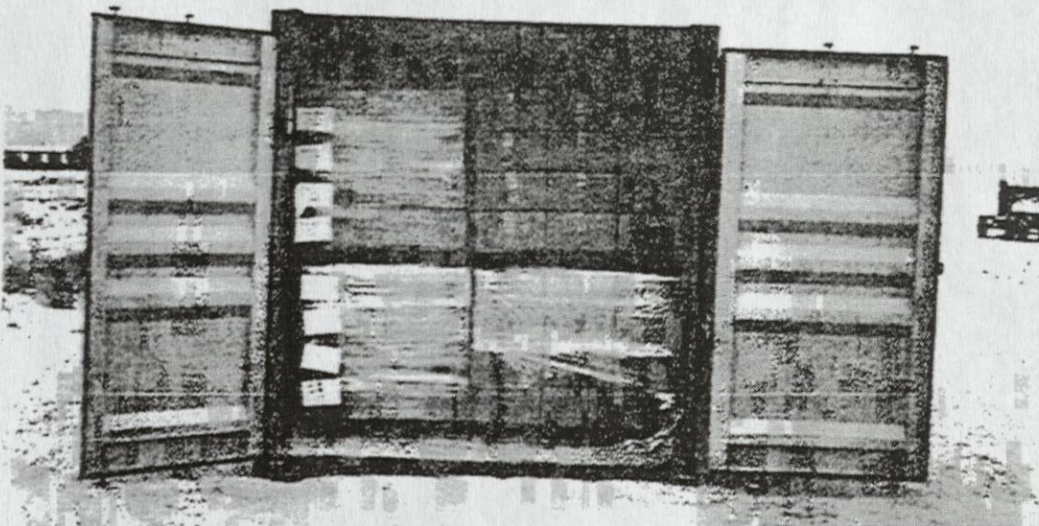


Figure 12. B Ration Container Van with Doors Open and Ration Cases Visible
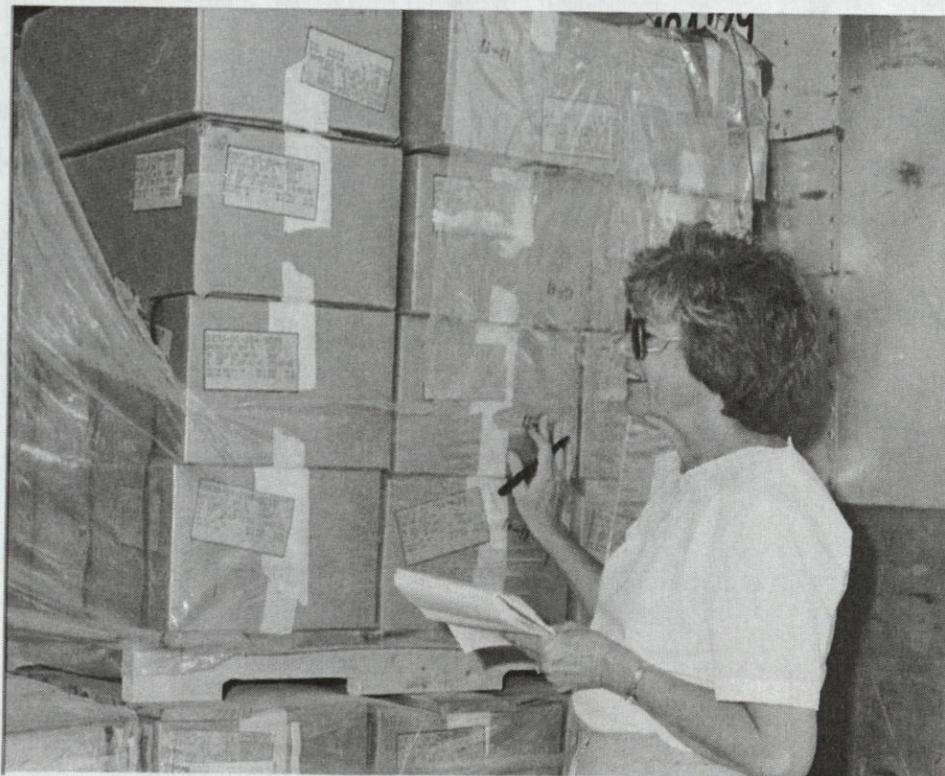
Figure 13   a.  T Ration Container Van with Doors Open and Ration Cases Visible
                  b.  Ms. Carol Shaw Checks T Ration Packages
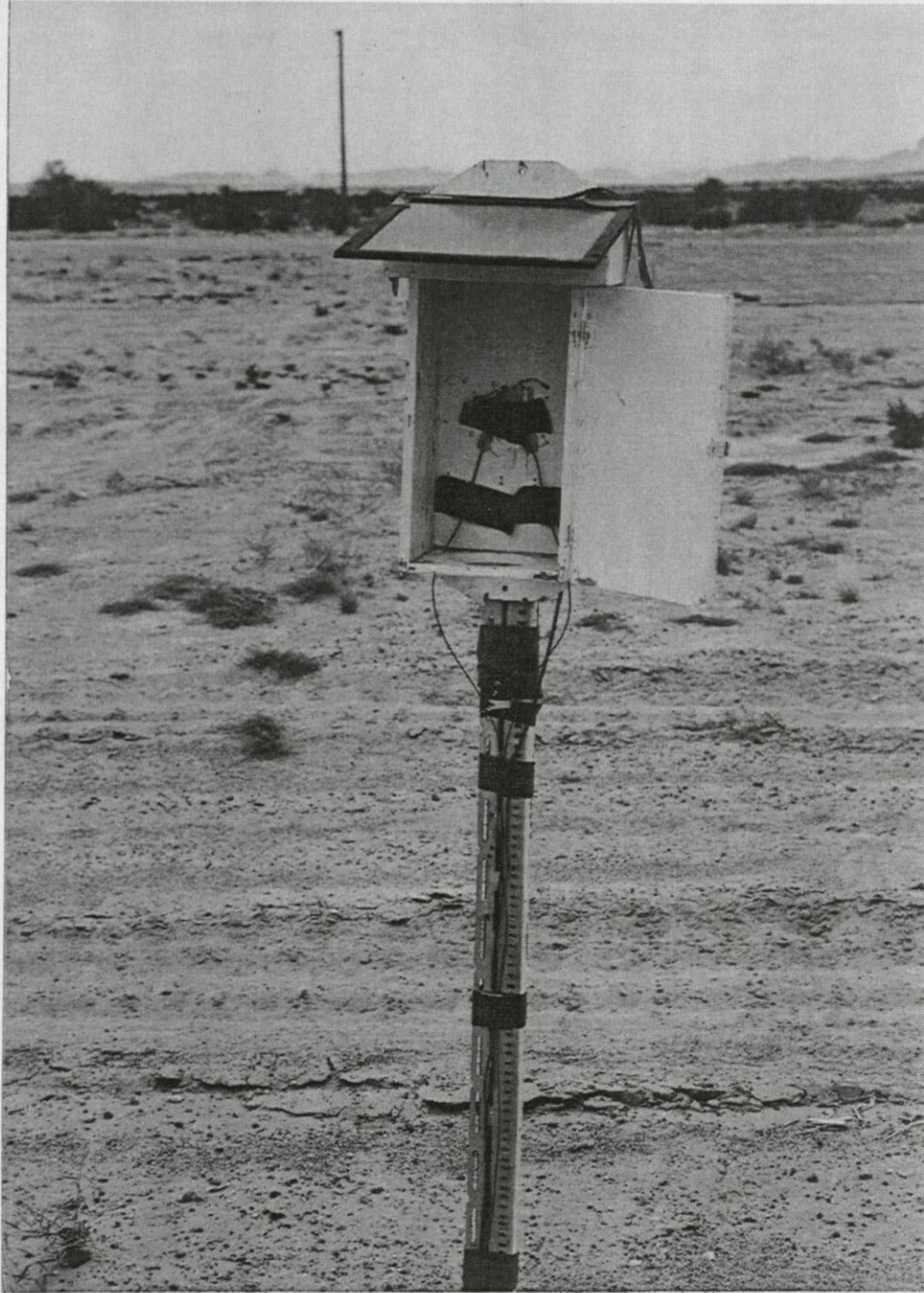
Figure 14.  Shelter with Thermocouples for Measuring Outside Ambient Air Temperature.  Door is closed during use.
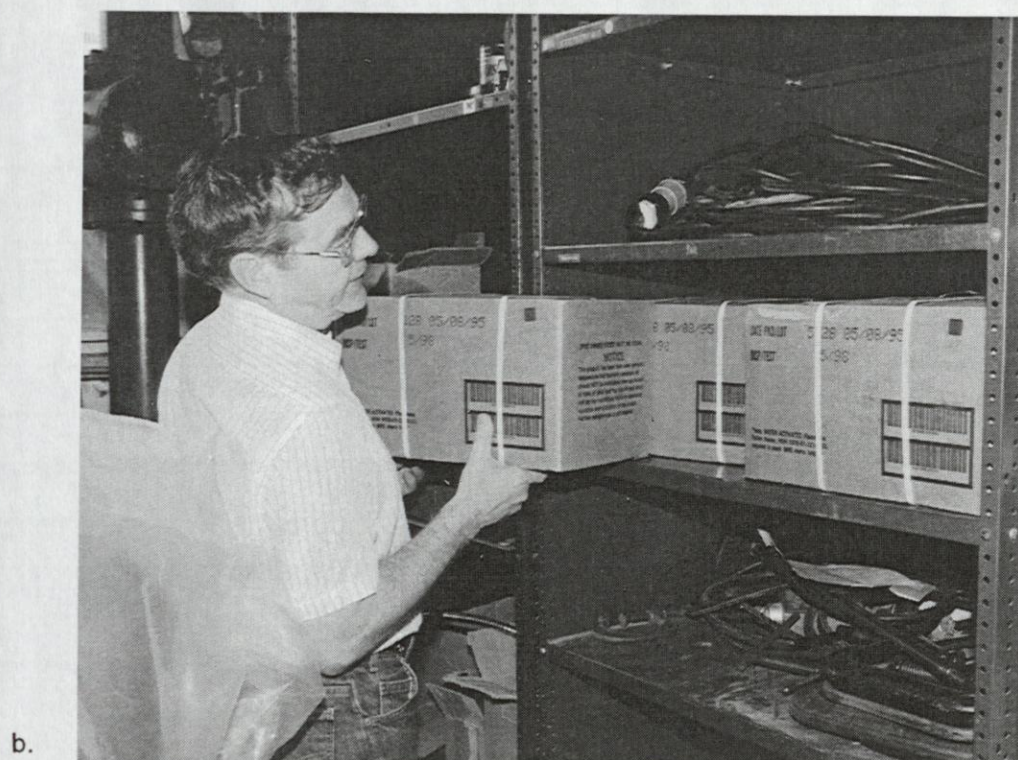
Figure 15  a.  Open Case of MRE Rations with Thermocouples Attached
           b.  Dr. Bruce Wright checks performance of TTIs on MRE packages

North

Row   1    2    3    4    5    6    7    8    9    10

South

<- 40' ->
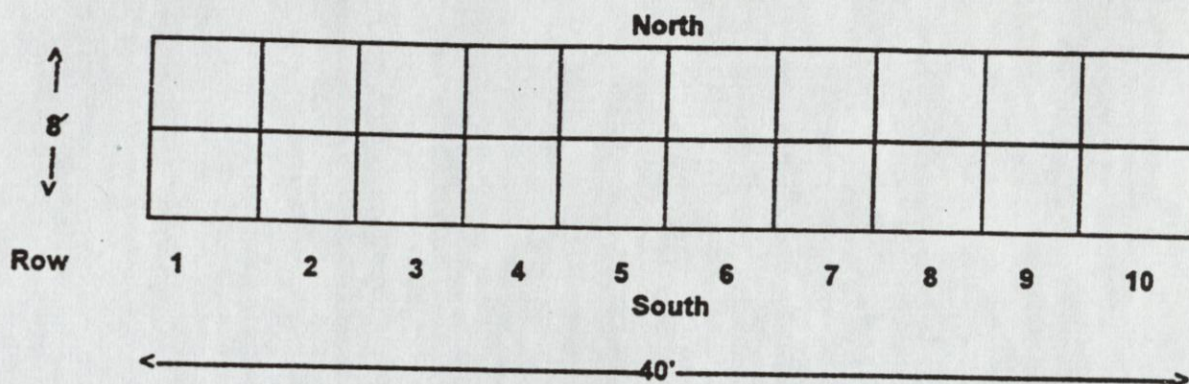
Figure 16.  View from Top Showing Container Van with Paired Rows.  Insulation on Top (Not Shown) Was Cardboard Cartons (Rows 6, 7, ½ of 8) and Rigid Foam with Foil Top and Bottom (½ of 8, Rows 9, 10).  *Not to scale.*

**Rows 1 to 5: no insulation on top**          **Rows 6 and 7, half of 8: Empty cardboard cartons on top**          **half of 8, Rows 9, 10: 1" rigid foam with foil top and bottom**

Row 1    2    3    4    5    6    7    8    9    10
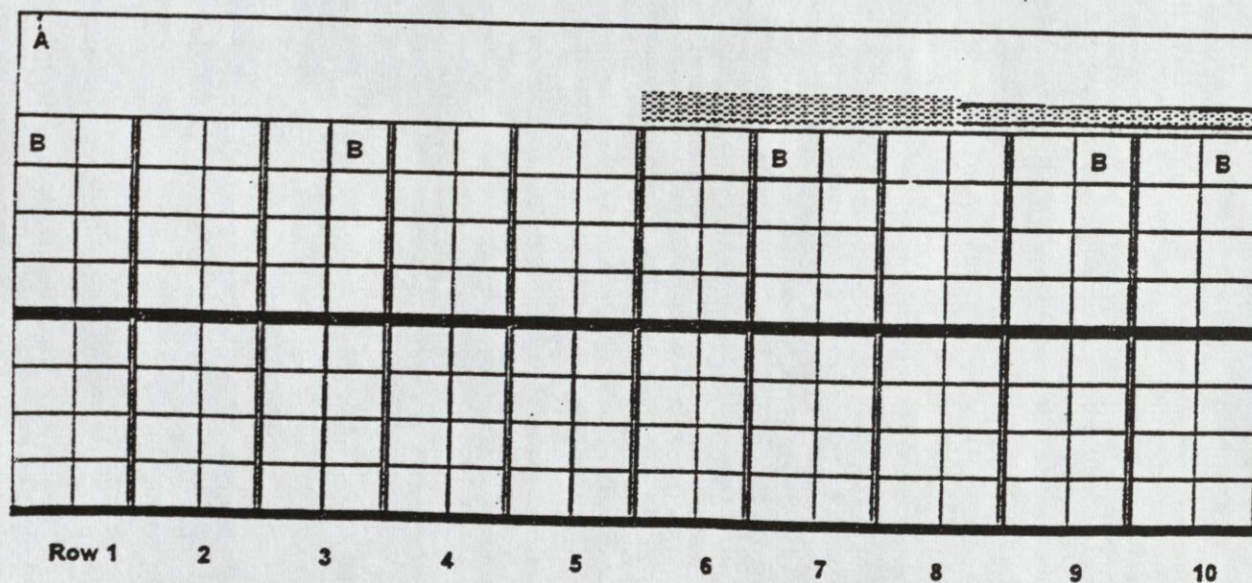
A = Thermocouple hanging 4" from roof        B = Thermocouple in interior of carton

Figure 17.   Side View of T Ration Storage in 10 (Paired) Rows of Four Tiers per Pallet.  MRE Ration Had 9 (Paired) Rows of Six Tiers per Pallet.  B Ration Had 10 (Paired) Rows with Cases of Varying Size Deparding on the Content.  *Not to scale.*

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**1** Outer circle is dark initially

**2** Inner disk darkens at increase in temperature over time

Bar Code and TTI Label
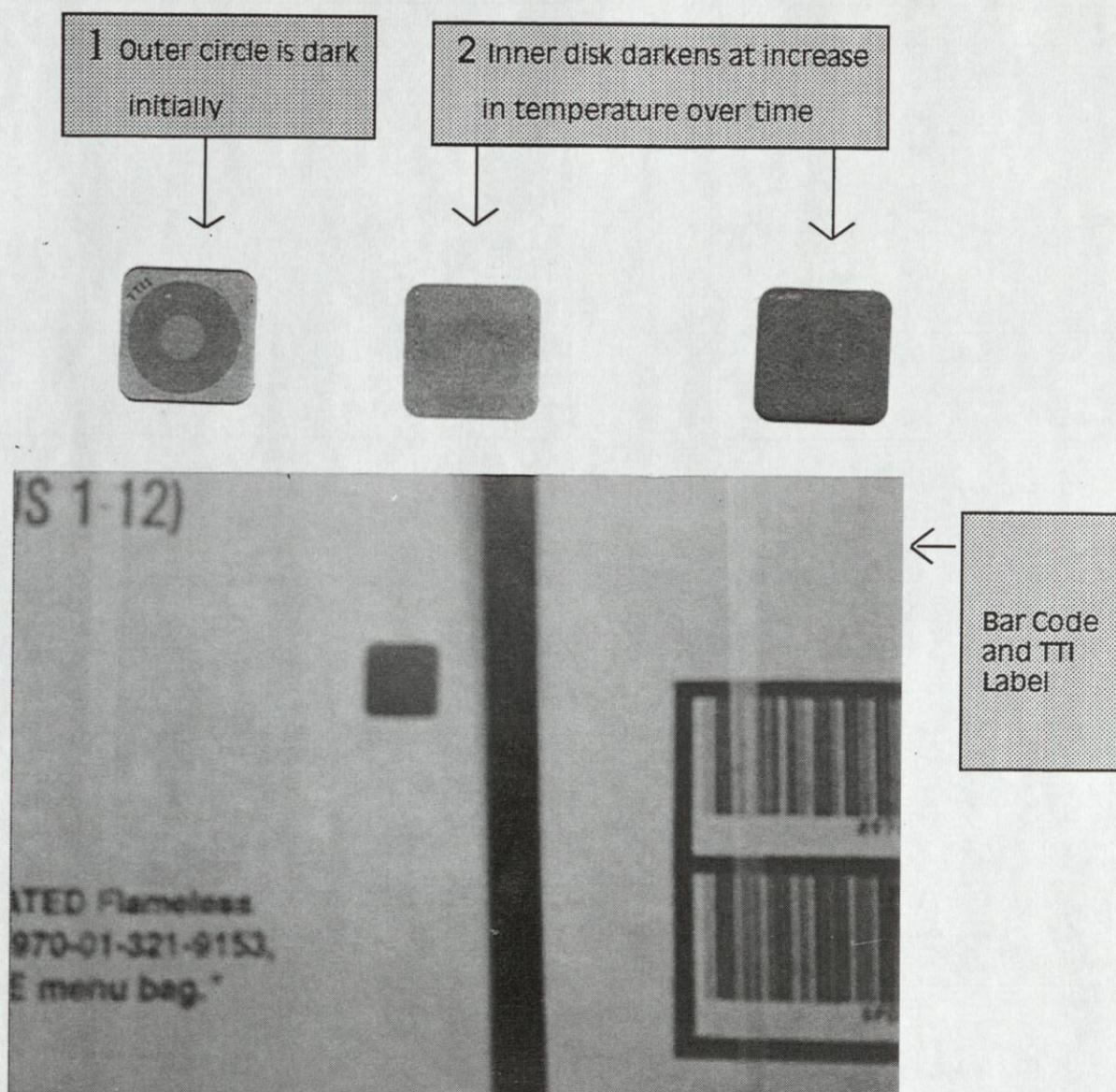
Figure 18. (Top) Darkening of Time-Temperature Indicator (TTI) Labels; (Bottom) Bar Code with TTI Label.

## MRE Van 1992
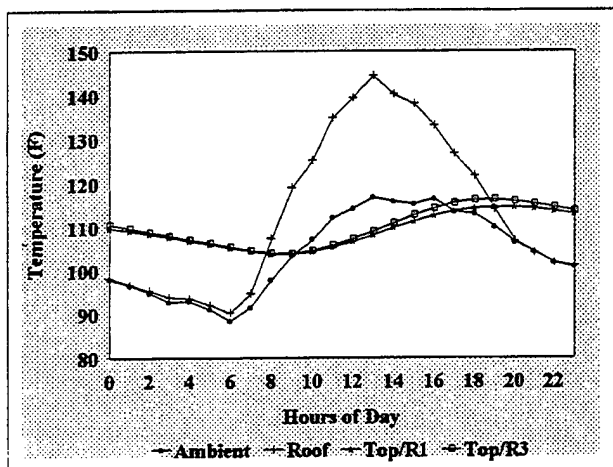


## MRE Van 1993
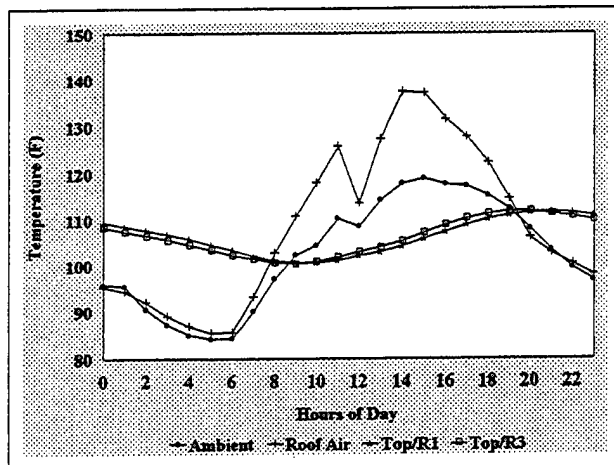


## B Ration Van 1992
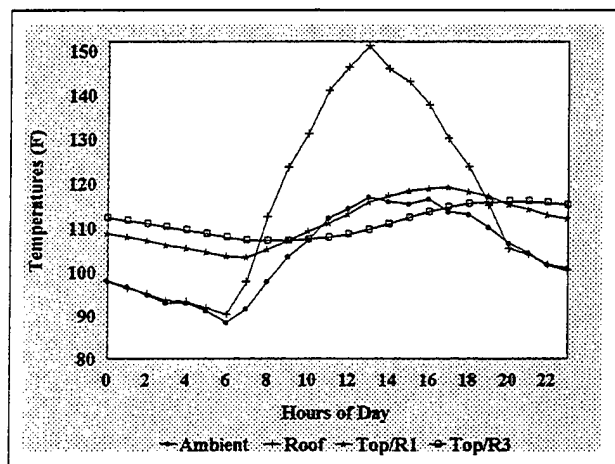


## B Ration Van 1993
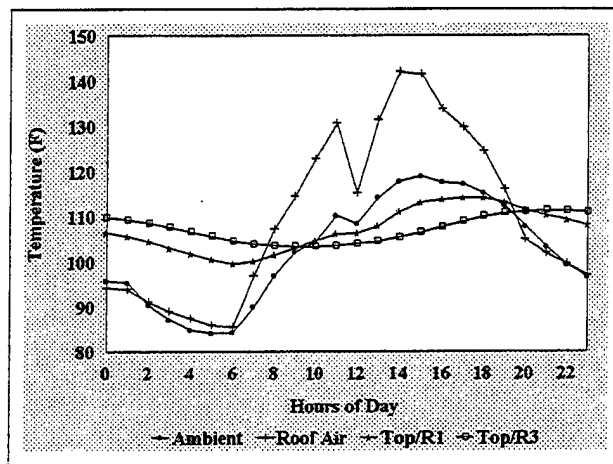


## T Ration Van 1992
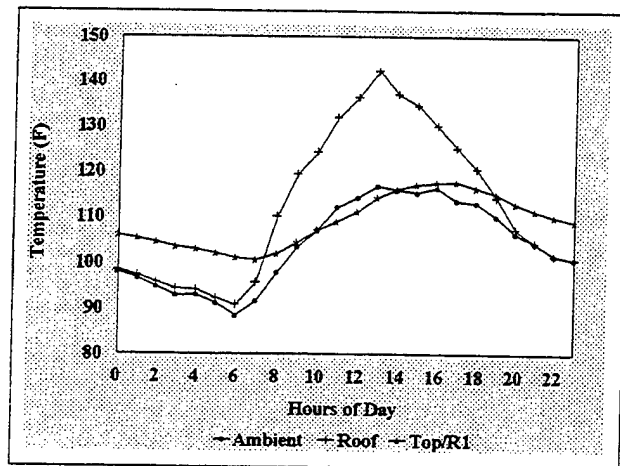


## T Ration Van 1993
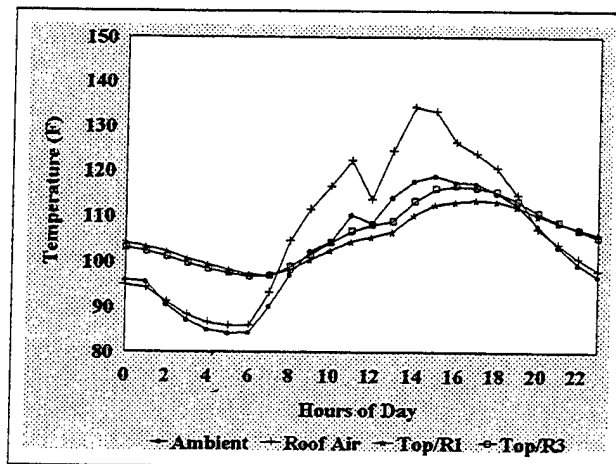


Figure 19. Temperatures in Container Vans and Outside Ambient Air on the Hottest
Summer Days of 1992 and 1993

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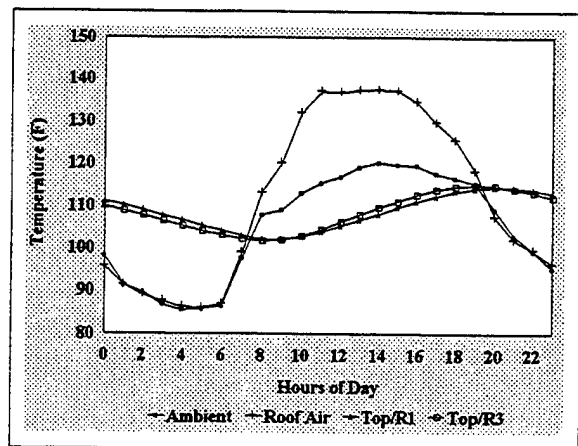
## MRE Van 1994
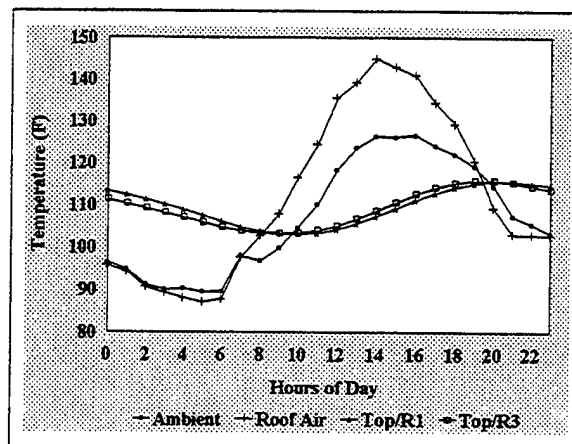
## MRE Van 1995

## B Ration Van 1994
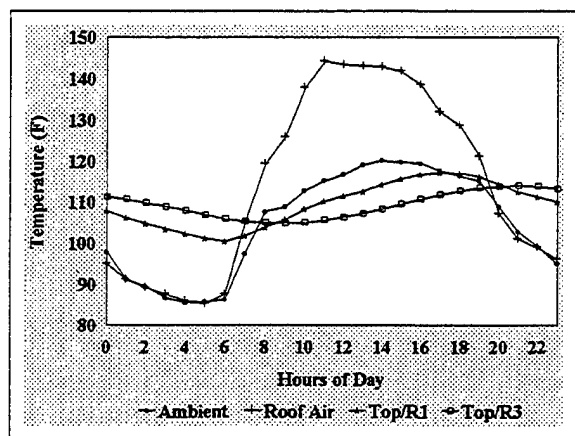
## B Ration Van 1995
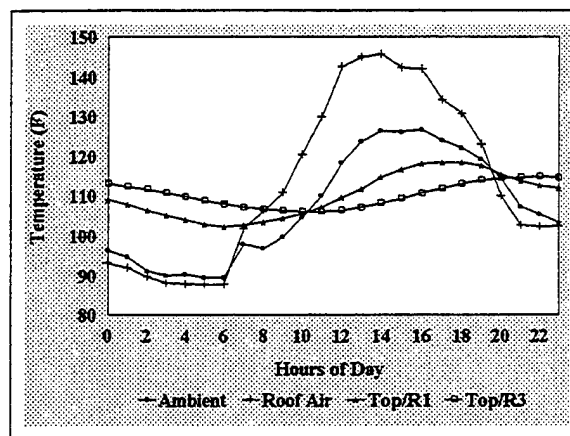
## T Ration Van 1994
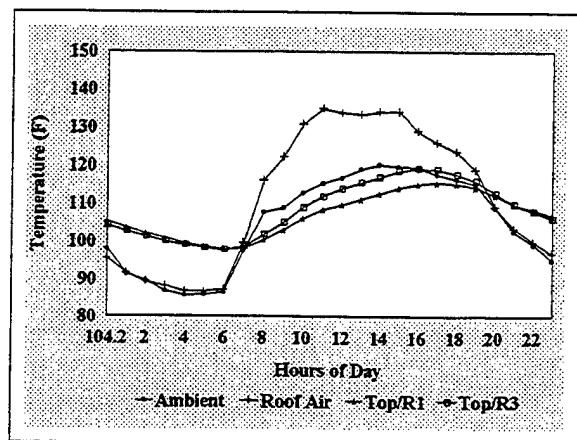
## T Ration Van 1995
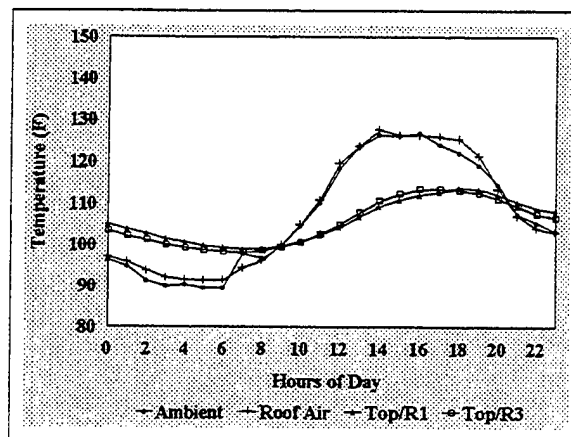
Figure 20. Temperatures in Container Vans and Outside Ambient Air on the Hottest
Summer Days of 1994 and 1995.

27
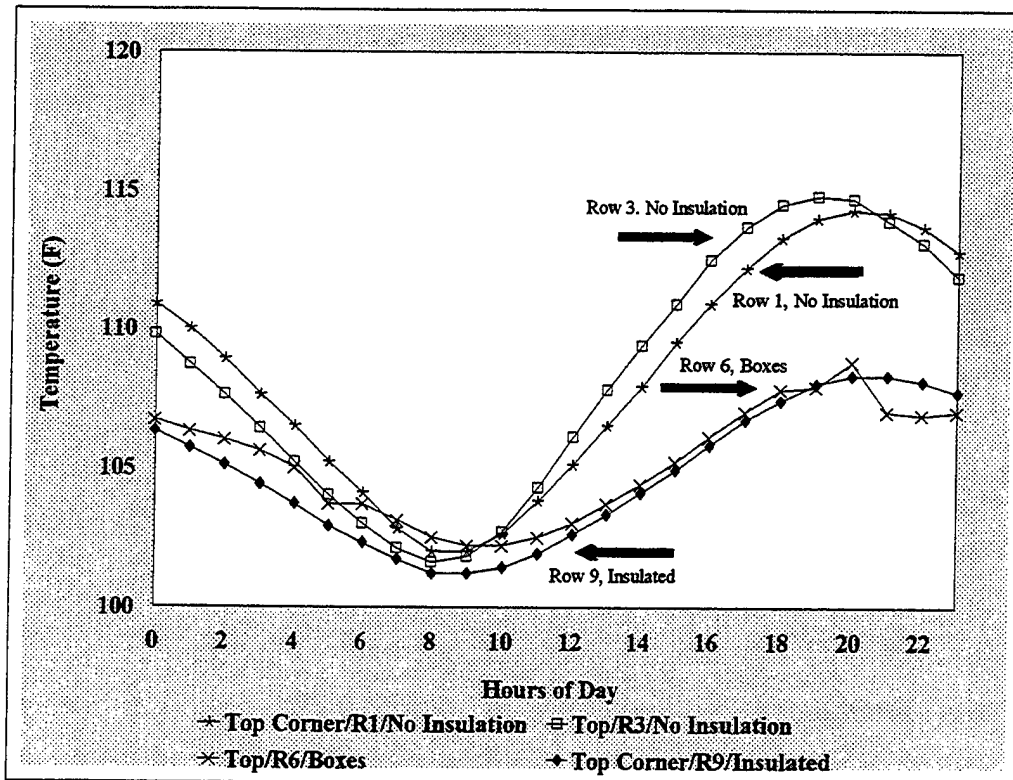
# MRE Van 1994



# MRE Van 1995
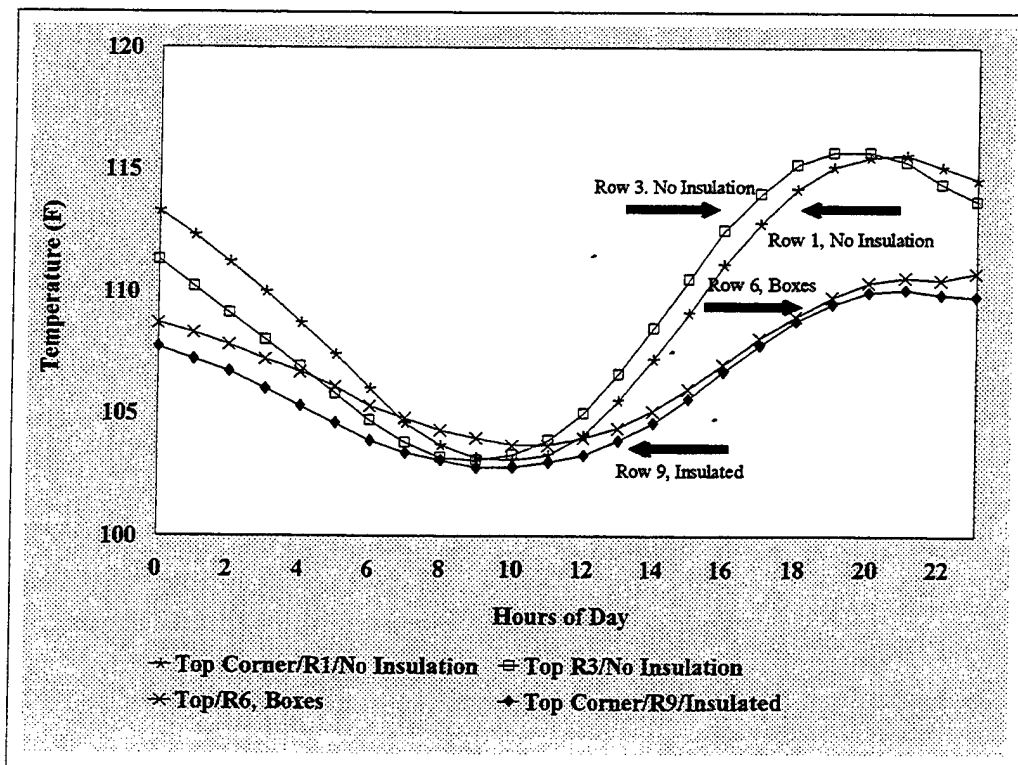


Figure 21.  MRE Van, Hottest Days 1994 and 1995, Top Rows without Insulation and
with Insulation or boxes.

## 1994, T Ration Van No Solar Shield
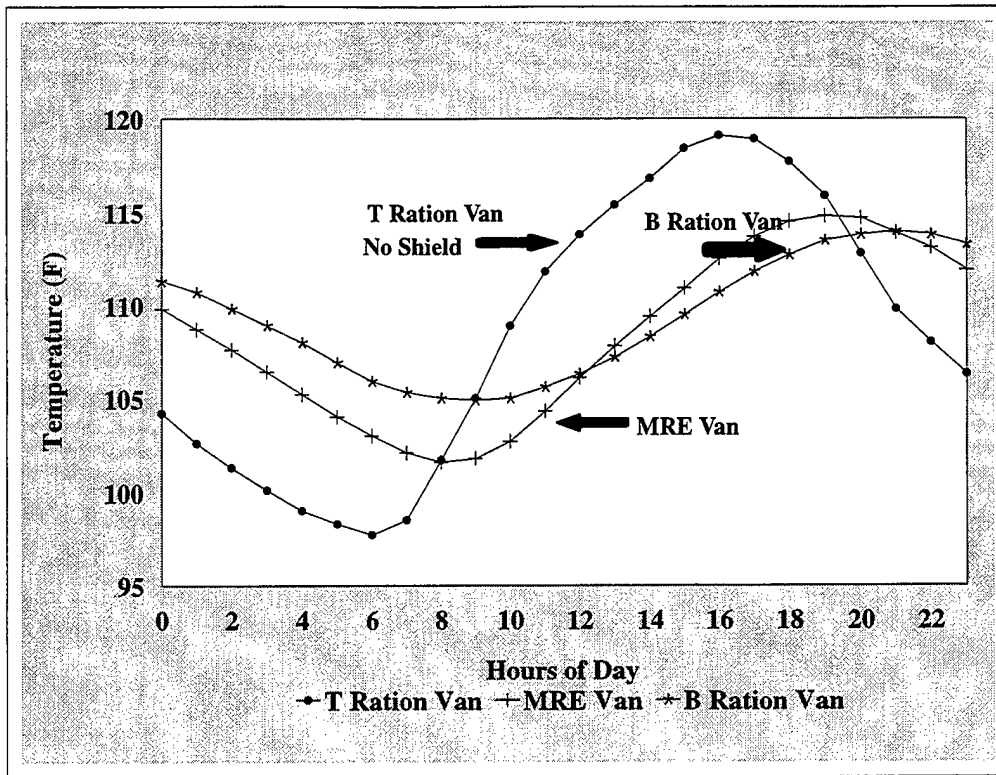


## 1995, T Ration Van With Solar Shield
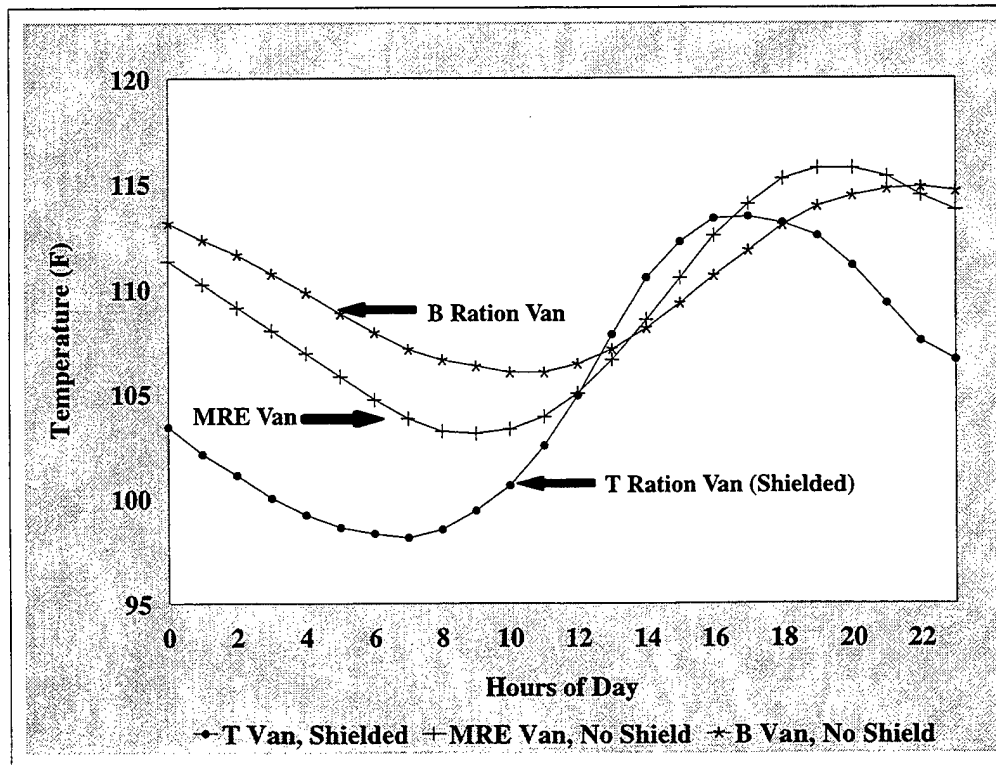


Figure 22. Temperatures of Top Row Cases (R3) on the Hottest Days of 1994 and 1995, T Ration Van with and without Solar Shield.

## MEAN MONTHLY TEMPERATURES, 1992-93

### TOP CASE AND AMBIENT AIR, MRE VAN

MEAN TEMPERATURE (F)



• AMBIENT AIR  ▲ TOP MIDDLE CASE AIR
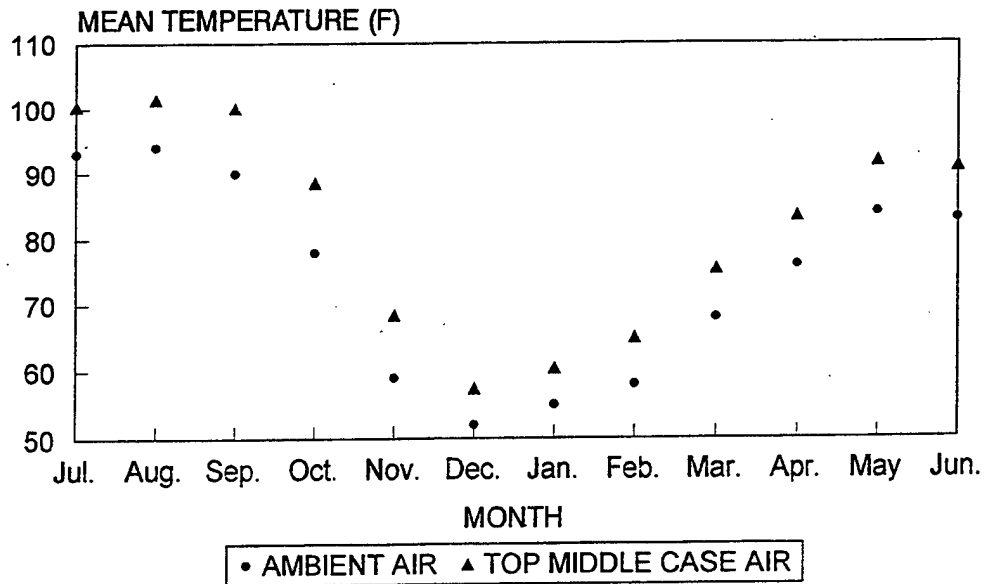
MONTH

Figure 23.  Mean Monthly Temperatures, Top Case and Ambient Air, MRE Van 1992-1993.

## MONTHLY MEAN TEMPERATURES, MRE VAN

### CASE VS. AMBIENT AIR, 1992-93

Top Case Air (Uninsulated, F)
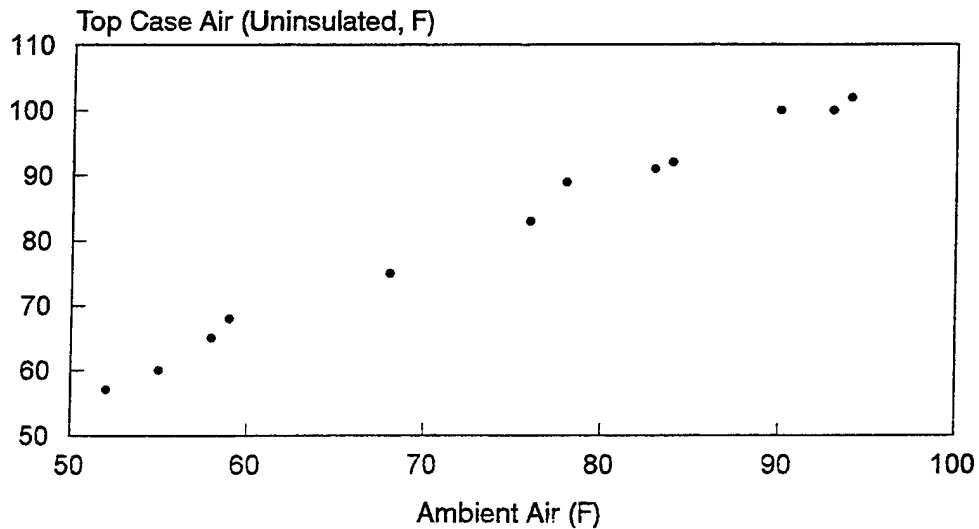


Ambient Air (F)

Figure 24.  Monthly Mean Temperatures, Case Vs. Ambient Air, MRE Van 1992-1993.

# Monthly Mean Temperatures 1994
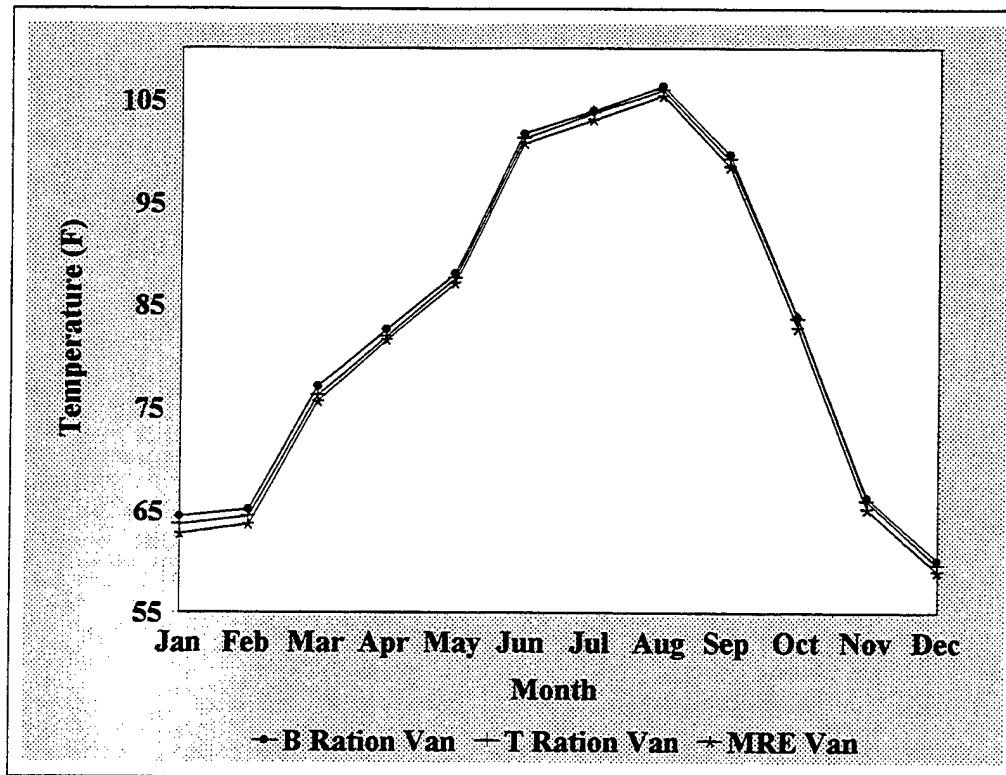


# Monthly Mean Temperatures 1995
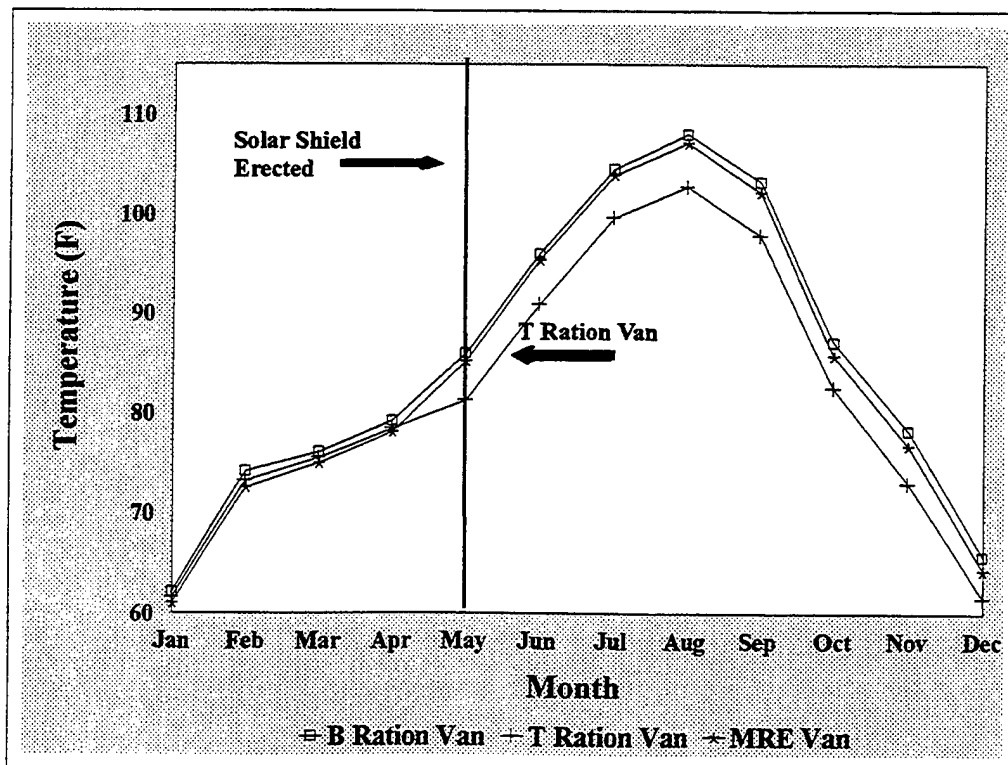


Figure 25. Monthly Mean Temperatures, Top Case Air (R3), B Ration, T Ration, MRE
Vans 1994 and 1995

## Monthly Mean Maximum Temperatures
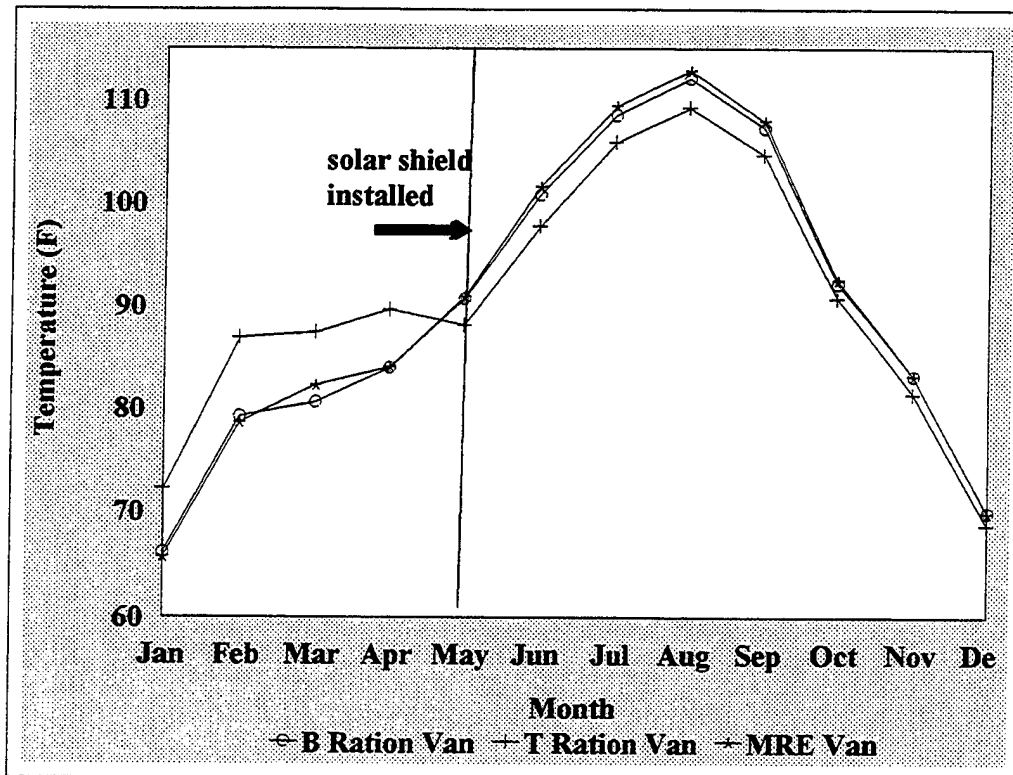


## Monthly Mean Minimum Temperatures
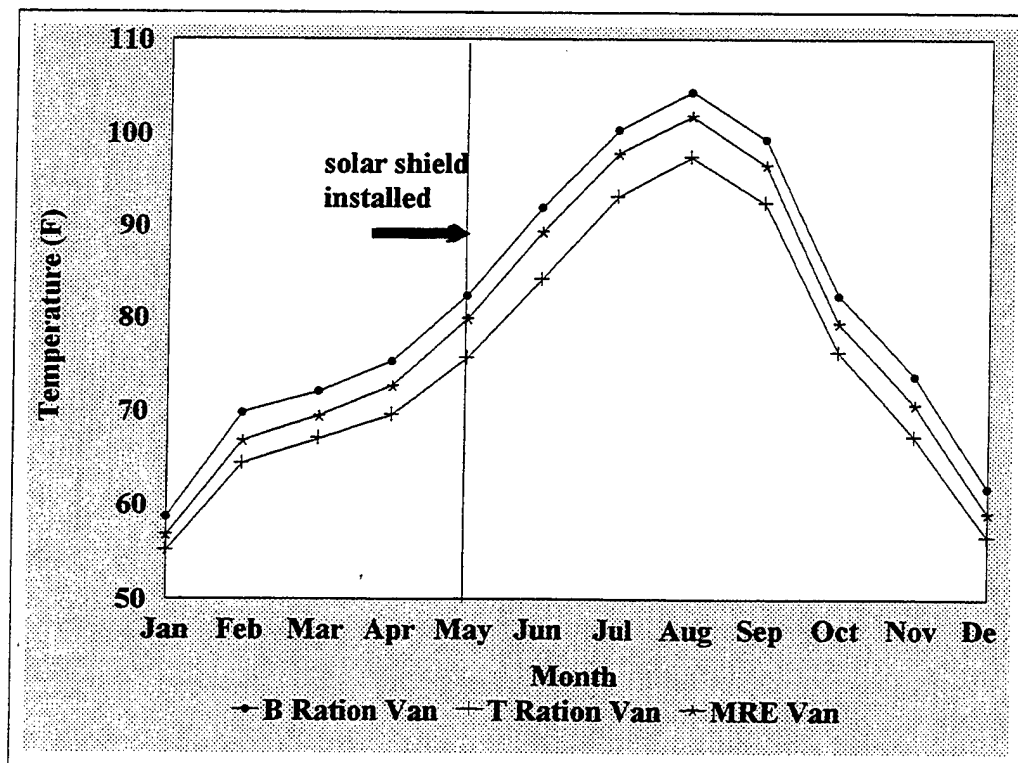


Figure 26. Monthly Mean Maximum and Mean Minimum Temperatures of Top Case
Air (R3), B Ration, T Ration, MRE Ration Vans 1995
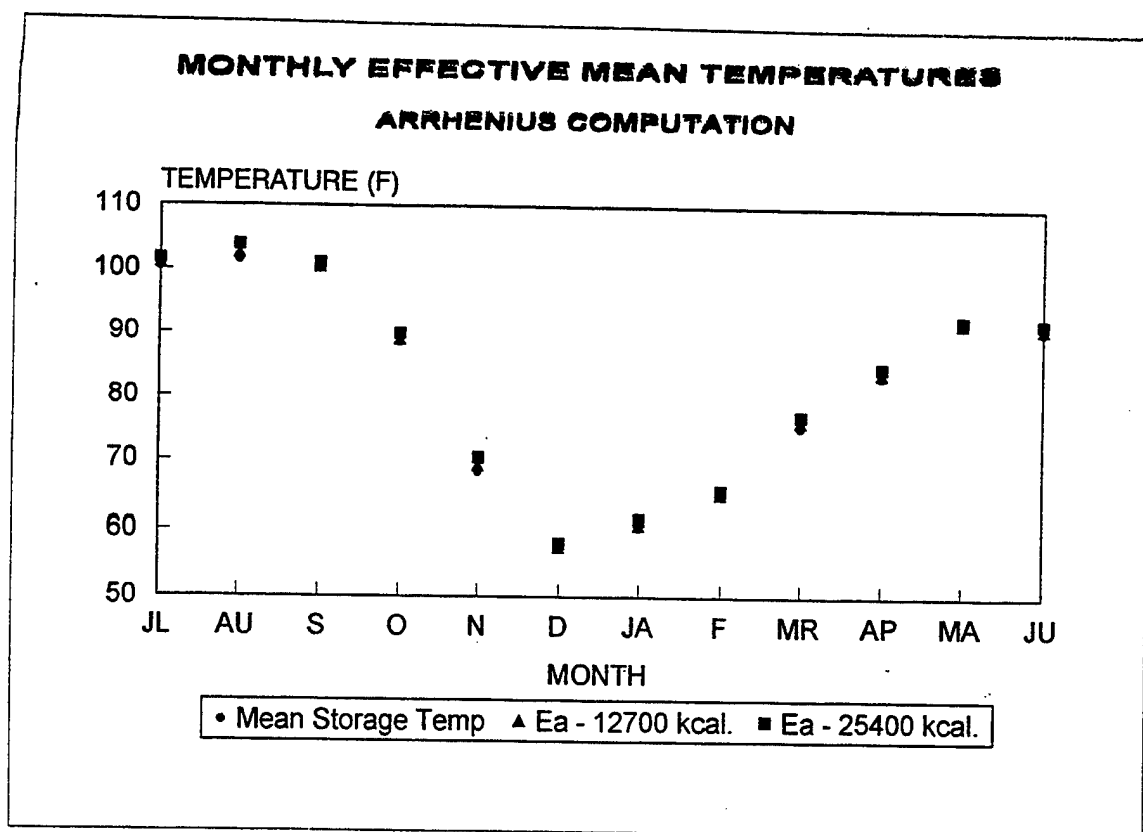
Figure 27. Monthly Effective Mean Temperatures, Arrhenius Computation.

# MRE Shelf Life Indicator
## TTI1: 3 years at 80° F
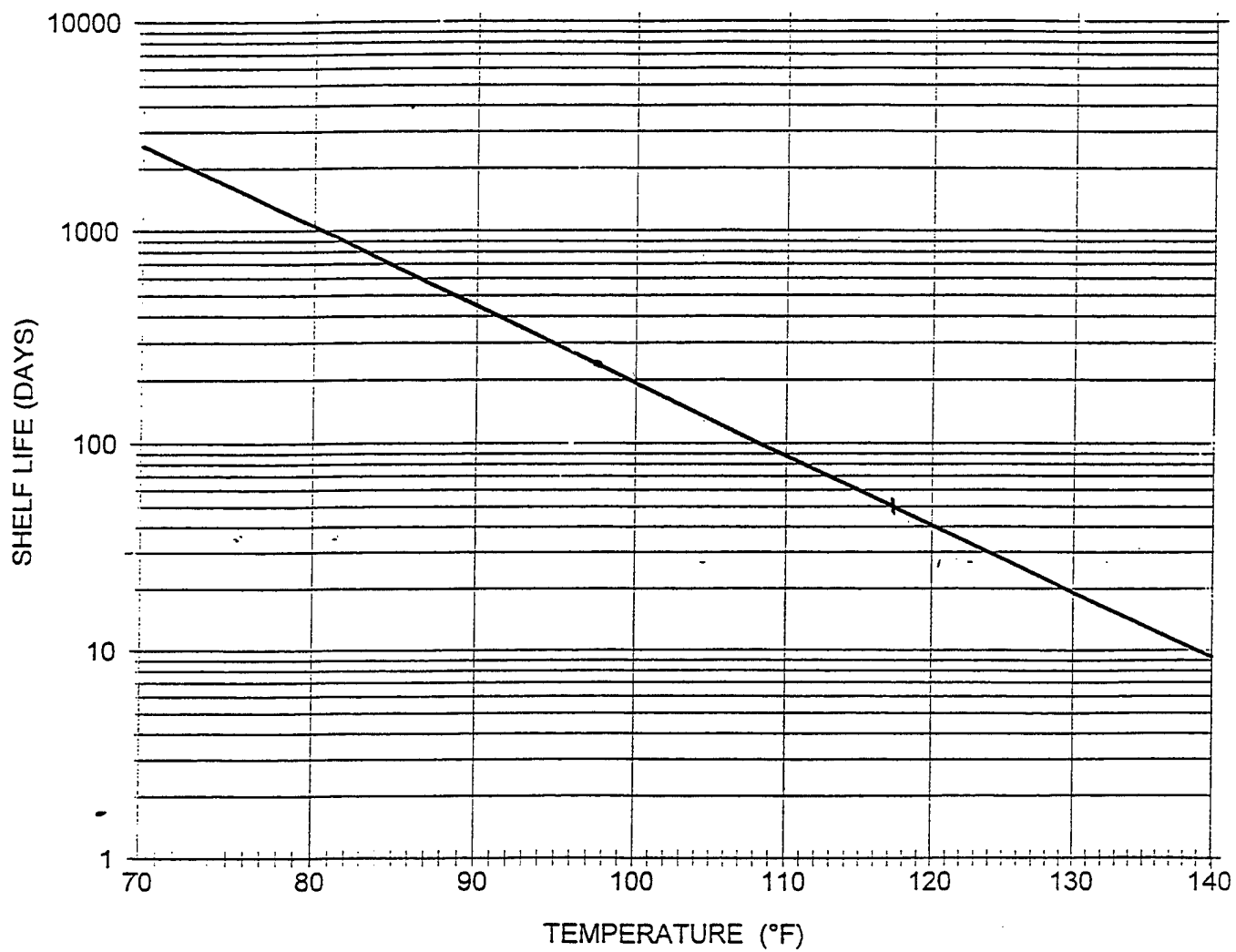


Figure 28. Prediction Curve for MRE Shelf Life Indicator Based on Three Years at 80 °F.
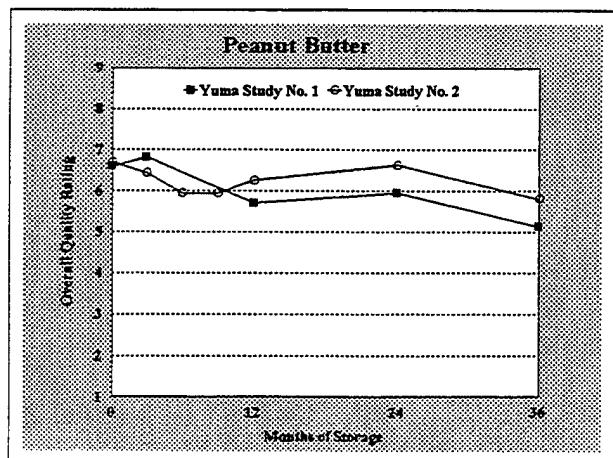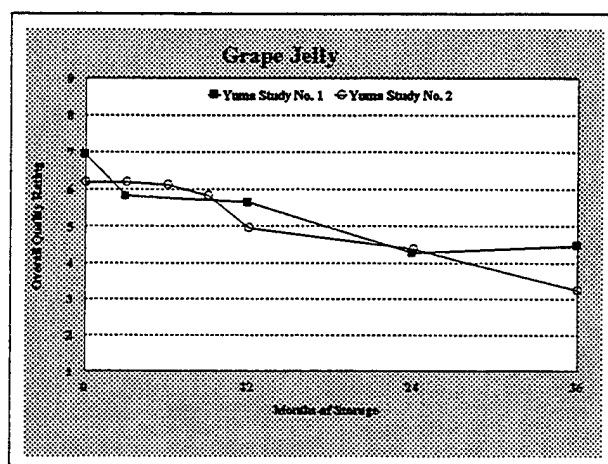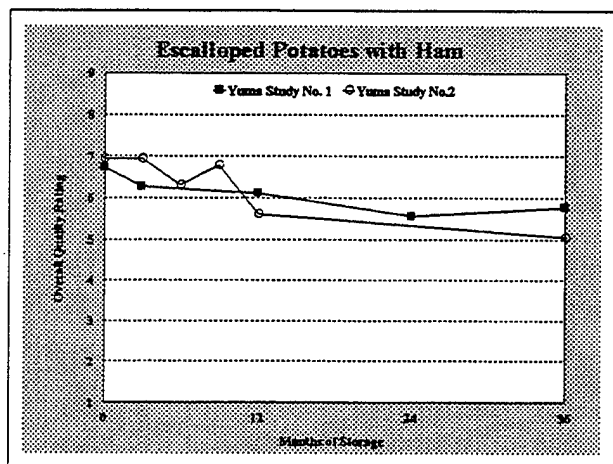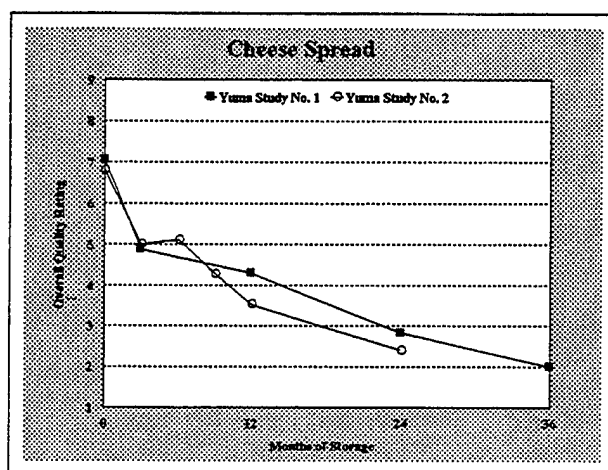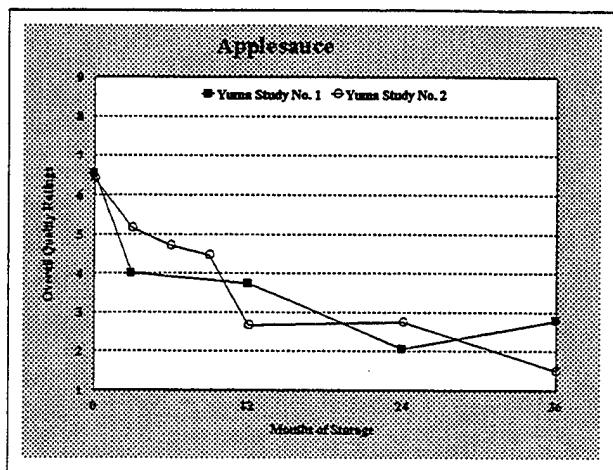
`1 = extremely poor, 9 = excellent

Figure 29. Overall Quality Ratings of Components Stored in Container Vans at Yuma, AZ, Study No. 1 and No. 2
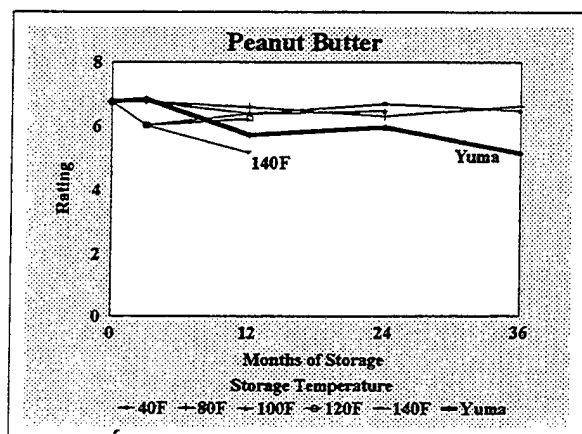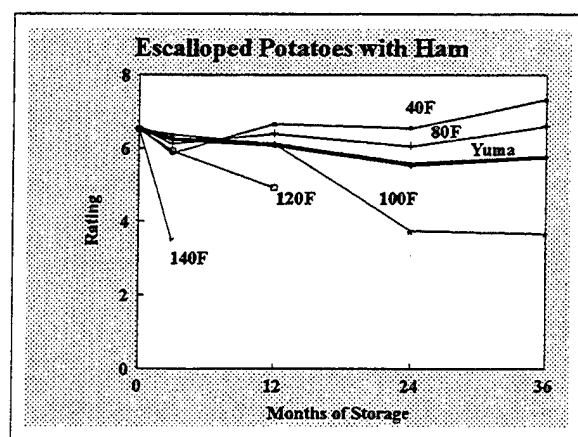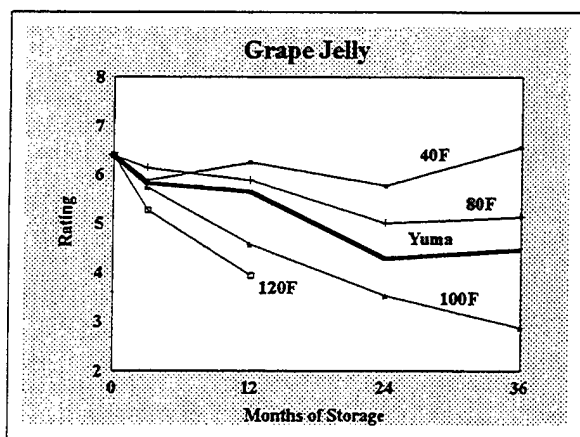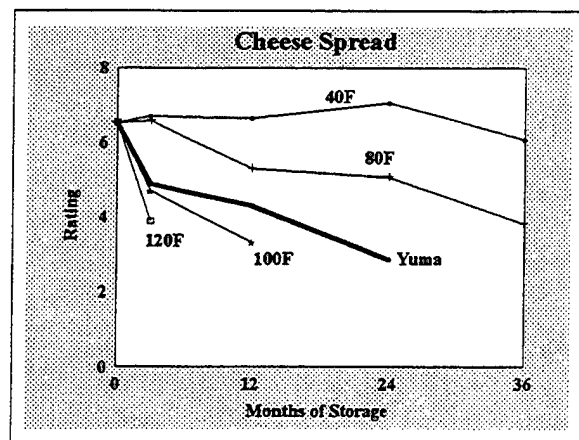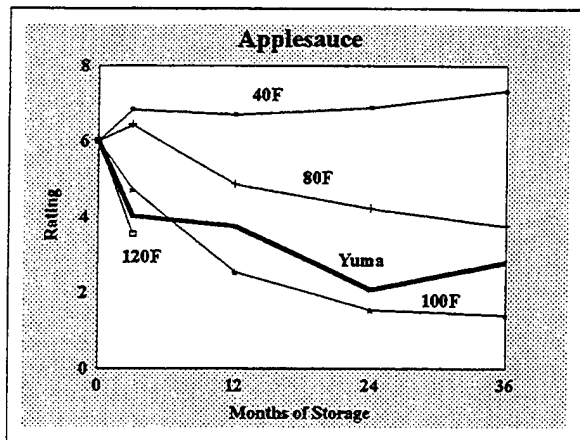
1 = extremely poor, 9 = excellent

Figure 30. Overall Quality Ratings of Components Stored in Container Vans at Yuma, AZ, and at Constant Temperatures, Study No. 1

36
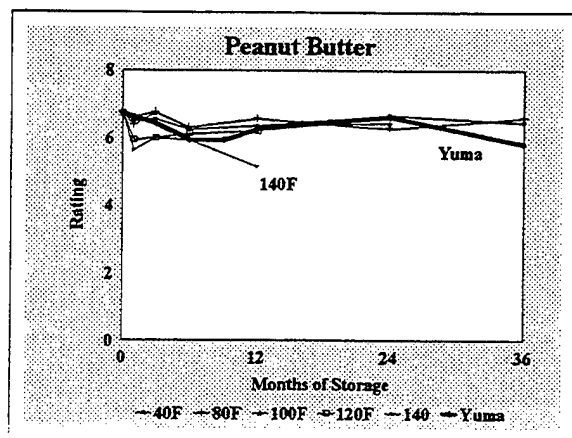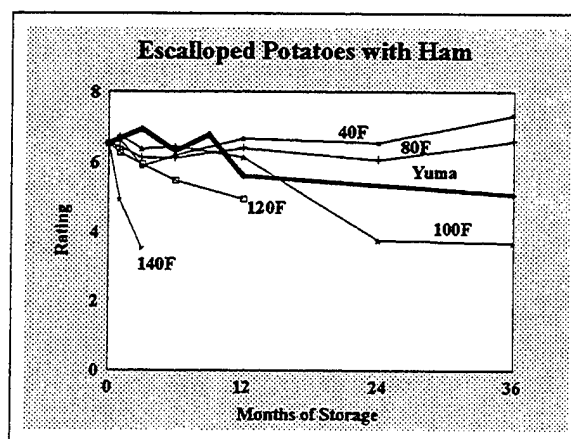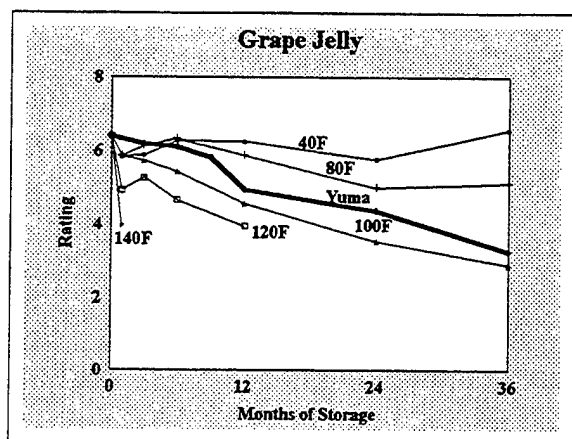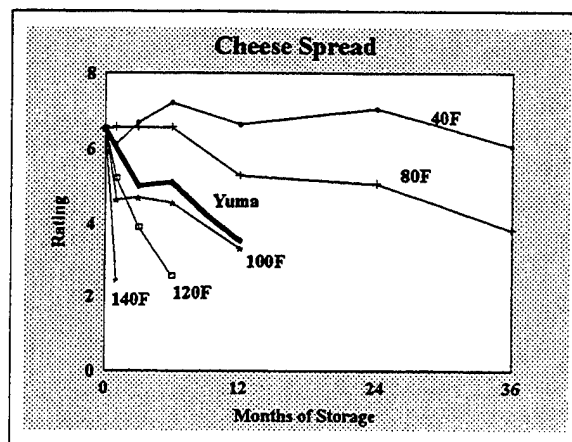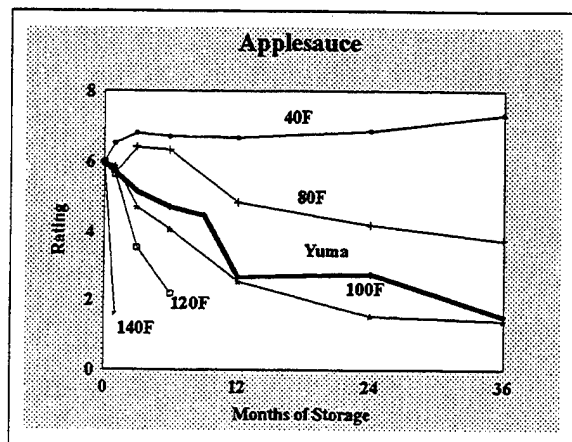
1 = extremely poor, 9 = excellent

Figure 31. Overall Quality Ratings of Components Stored in Container Vans at
Yuma, AZ, and at Constant Temperatures, Study No. 2

100 = white, 0 = black
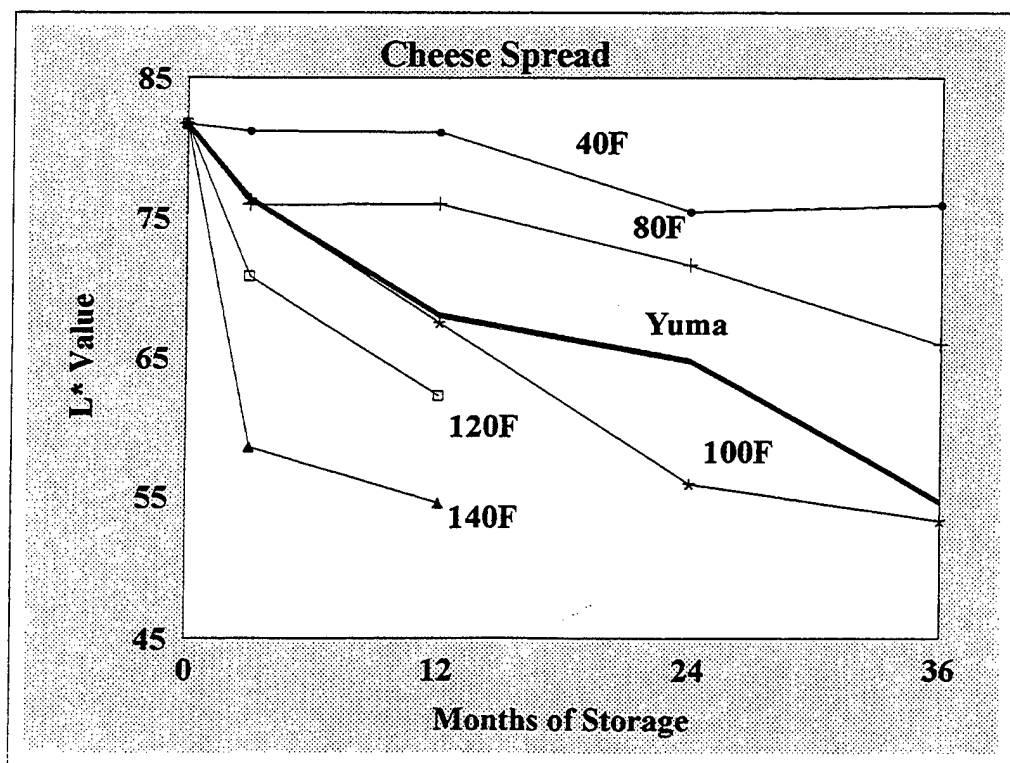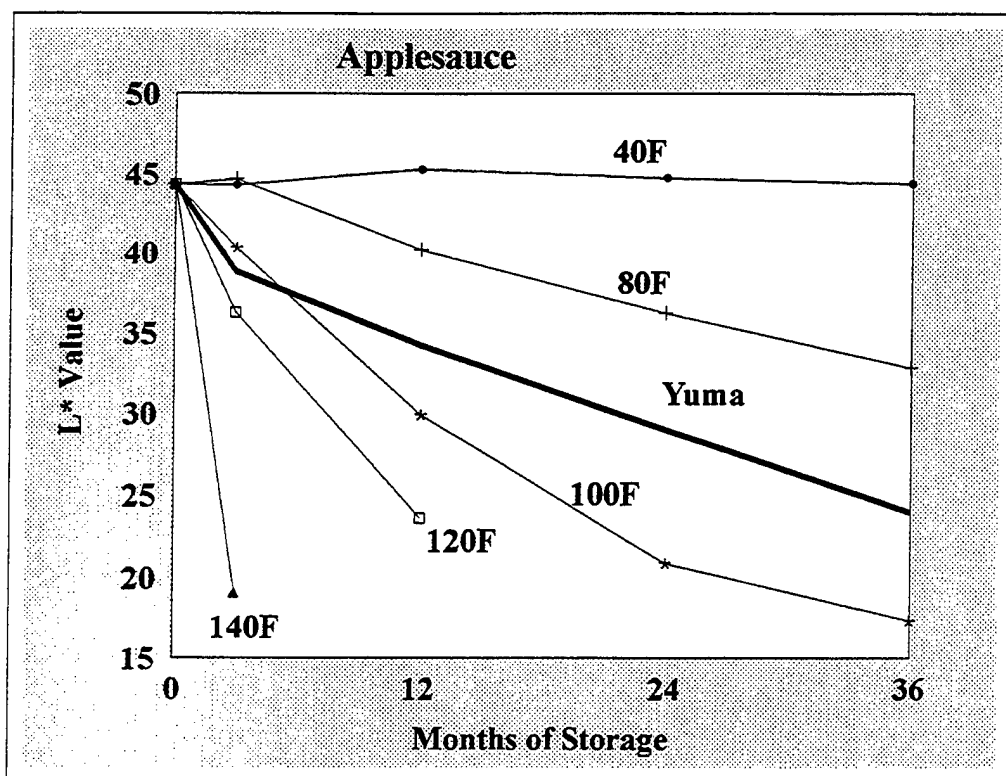


Figure 32.  L* Values of Applesauce and Cheese Spread Stored at Constant
             Temperatures at Natick MA and in Container Vans at Yuma AZ,
             Study No. 1.

38
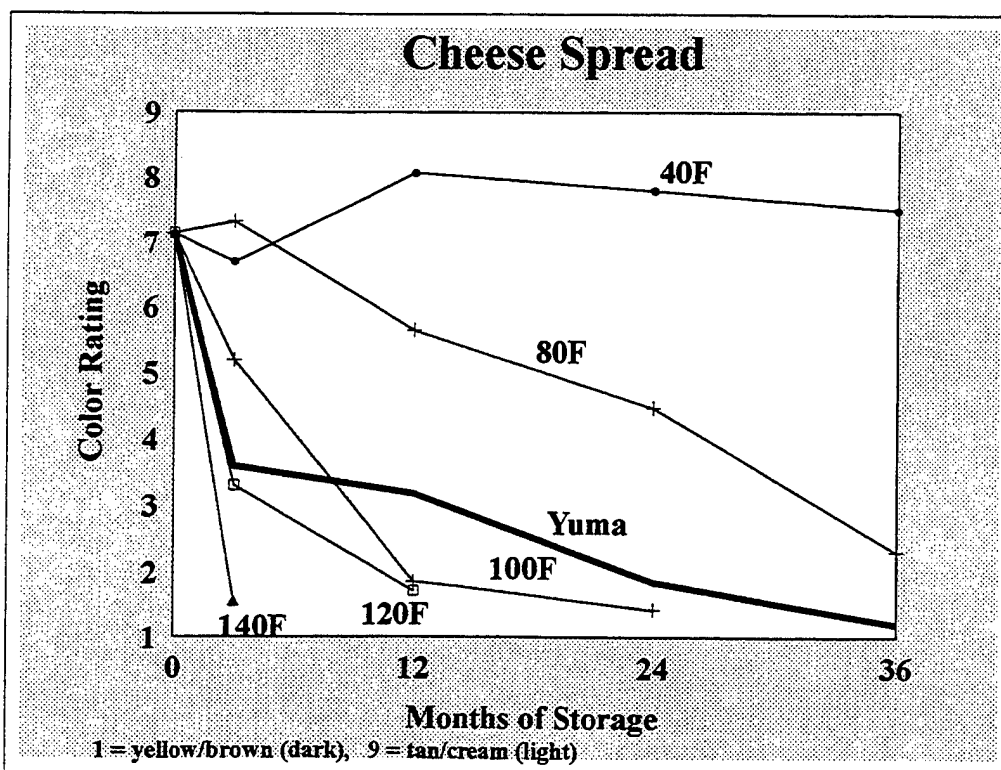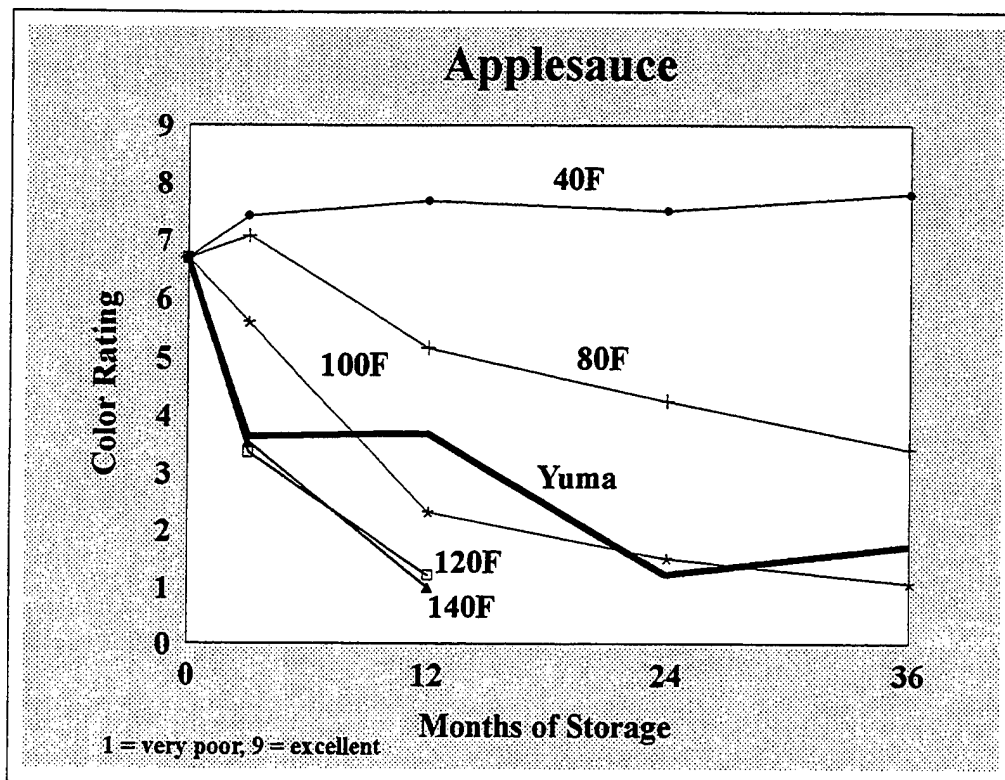
Figure 33. Color Ratings of Applesauce and Cheese Spread Stored in Container
Vans at Yuma and at Constant Temperatures at Natick, Study No. 1

# VI. TEXT TABLES

# Table 1. Exterior Physical Characteristics of Vans

| Ration Type | Exterior Dimensions | Color | Roof | Composition | | | Configuration | | Door |
| | | | | Walls | Door | Roof | Walls | |
|---|---|---|---|---|---|---|---|---|---|
| B Ration | 8'x8'x40' | Dark Brown Rustoleum | Steel Single Sheet | Steel Single Sheet | Steel Single Sheet | Fluted 9"-4" Transverse | Fluted 9"-4" Vertically, East End Horizontally | | Flat |
| MRE | 8'x8'x40' | Lighter Rustoleum | Steel Single Sheet | Steel Single Sheet | Steel Single Sheet | Fluted 9"-4" Transverse | Fluted 9"-4" Vertically, East End Horizontally | | Flat |
| T Ration | 8'x8'x40' | Dirty Light Grey | Steel Single Sheet | Steel Single Sheet | Steel Double Sheet | Flat | Ribbed Every 2' Vertically | | Flat |

# Table 2. Interior Physical Characteristics of Vans

| Ration Type | Floor | Sheathing | Head Space | From Walls or Other Pallets | Door to Pallets |
|---|---|---|---|---|---|
| B Ration | Wood over Steel | None | 13" | Flush with Walls 2-3" Between North And South Pallets | 2.5 Feet |
| MRE | Wood over Steel | None | 18" | 4-5" Walls to Pallets | 8" |
| T Ration | Wood over Steel | 1/4" Plywood Floor to 4' | 11" | 2" Left, 1" Right Walls to Pallets | 2 Feet |

**Table 3.  Characteristics of Container Van Loads**

| Ration Type | Weight (Lb) | | | Rows (Side) | High (Length) | Rows | Date of Pack | Ration Contents |
|---|---|---|---|---|---|---|---|---|
| | Gross | Tare | Net | | | | | |
| B Ration | 67200 | 7520 | 59680 | 2 | 2 | 10 | 14 Feb 91 | Unitized B Rations 100 Man Modules |
| MRE | 67120 | 8500 | 58620 | 2 | 2 | 9 | 22 Jan 91 | Meal, Ready-to-eat Individual 12 Meals/case |
| T Ration | 67200 | 6000 | 61200 | 2 | 2 | 10 | Jan 91 | Unitized Tray Packs 36 Person Modules |

The column header "Stacking (Pallets)" spans the Rows (Side), High (Length), and Rows columns.

## Table 4. Location of Container Van Thermocouples Used in Data Analyses

| B Ration | | T Ration | | MRE | | |
|---|---|---|---|---|---|---|
| Thermo-couple Number | Code | Thermo-couple Number | Code | Thermo-couple Number | Code | Location |
| 1 | AA1 | | | | | Ambient Air (Shelter) |
| 4 | B1RTA | 16 | T1RTA | 28 | M1RTA | Roof Air (hanging 4" below roof) |
| 5 | B1ST | 17 | T1ST | 29 | M1ST | SW corner, inside top case, uncovered |
| 7 | B3ST | 19 | T3ST | 31 | M3ST | Row 3 south, inside top case, uncovered |
| 8 | B3SM | 20 | T3SM | 32 | M3SM | Row 3 south, inside case below top layer |
| 9 | B6ST | 21 | T6ST | 33 | M6ST | Row 6 south top, inside top carton covered with empty cartons |
| 11 | B8ST | 23 | T8ST | 35 | M8ST | Row 8 south, inside top carton covered with 1" double foil-faced styrofoam insulation |
| 13 | B9ST | 25 | T9ST | 37 | M9ST | SE corner, inside top carton covered with 1" double foil-faced styrofoam insulation |

NOTE: Additional placements of thermocouples are shown in Appendix A.

# Table 5.  Temperatures (°F) on Hottest Day:  Ration Container Vans 1992 and 1993

## A.  MRE Van

| Thermocouple Row Number | Outside Ambient | | Inside Roof Air | | Top Cases, Corner No Insulation | | Top Cases, Middle No Insulation | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 28 | | 29 R1 | | 31 R3 | |
| | 1992 | 1993 | 1992 | 1993 | 1992 | 1993 | 1992 | 1993 |
| Mean (°F) | 104 | 102 | 113 | 108 | 109 | 106 | 110 | 106 |
| S.D. | 9.2 | 11.4 | 17.8 | 16.5 | 3.8 | 3.8 | 4.3 | 3.9 |
| Maximum (°F) | 117 | 119 | 144 | 137 | 115 | 112 | 116 | 112 |
| Minimum (°F) | 88 | 84 | 90 | 86 | 104 | 101 | 104 | 100 |

## B.  B Ration Van

| Thermocouple Row Number | Outside Ambient | | Inside Roof Air | | Top Cases, Corner No Insulation | | Top Cases, Middle No Insulation | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 4 | | 5 R1 | | 7 R3 | |
| | 1992 | 1993 | 1992 | 1993 | 1992 | 1993 | 1992 | 1993 |
| Mean (°F) | 104 | 102 | 115 | 110 | 111 | 107 | 111 | 107 |
| S.D. | 9.2 | 11.4 | 20.3 | 18 | 5.2 | 4.7 | 3.2 | 2.8 |
| Maximum (°F) | 117 | 119 | 151 | 142 | 119 | 114 | 116 | 111 |
| Minimum  (°F) | 88 | 84 | 90 | 86 | 103 | 100 | 107 | 104 |

## C.  Tray Ration Van

| Thermocouple Row Number | Outside Ambient | | Inside Roof Air | | Top Cases, Corner No Insulation | | Top Cases, Middle No Insulation | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 16 | | 17 R1 | | 19 R3 | |
| | 1992 | 1993 | 1992 | 1993 | 1992 | 1993 | 1992 | 1993 |
| Mean (°F) | 104 | 102 | 112 | 107 | 109 | 106 | 111 | 106 |
| S.D. | 9.2 | 11.4 | 16.5 | 15.3 | 5.7 | 6.5 | 7.0* | 6.5 |
| Maximum (°F) | 117 | 119 | 142 | 134 | 118 | 114 | 122* | 117 |
| Minimum (°F) | 88 | 84 | 91 | 86 | 101 | 97 | 101 | 97 |

* Possibly Defective Positioning of Thermocouples

**Table 6. Hottest Day of 1993, Day 213 (August 1), Temperatures and Temperature Changes from Selected Thermocouples**

A.  Temperatures (°F)

| Day 213 | Ambient | Top Carton | Roof Air | | |
| Hour | Air | Air MRE | MRE | B Ration | Tray |
|---|---|---|---|---|---|
| 1000 | 104.4 | 100.9 | 118.0 | 122.7 | 116.6 |
| 1100 | 110.3 | 101.8 | 125.7 | 130.6 | 122.3 |
| 1200 | 108.5 | 103.0 | 113.5 | 115.2 | 113.7 |
| 1300 | 114.2 | 104.0 | 127.2 | 131.3 | 124.5 |

B.  Change from Previous Hour (°F)

| Day 213 | Ambient | Top Carton | Roof Air | | |
| Hour | Air | Air MRE | MRE | B Ration | Tray |
|---|---|---|---|---|---|
| 1000 | | | | | |
| 1100 | 5.9 | 0.9 | 7.7 | 7.9 | 5.7 |
| 1200 | -1.8 | 1.2 | -12.2 | -15.4 | -8.6 |
| 1300 | 5.7 | 1.0 | 13.7 | 16.1 | 10.8 |

# Table 7.   Mean Temperatures (°F), Hottest Days 1992-1995

## A.   MRE Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 104 | 102 | 105 | 107 | 105 |
| Roof Air | | 28 | 113 | 108 | 112 | 112 | 111 |
| Top Carton  Corner | No Insulation | 29 | 109 | 106 | 108 | 109 | 108 |
| | Insulation | 37 | 109 | 107 | 108 | 108 | 108 |
| Middle | No Insulation | 31 | 110 | 106 | 108 | 109 | 108 |
| | Insulation | 35 | 108 | 103 | 105 | 106 | 105 |
| | Empty Case | 33 | 108 | 104 | 105 | 107 | 106 |

## B.   B Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 104 | 102 | 105 | 107 | 105 |
| Roof Air | | 4 | 115 | 110 | 115 | 113 | 113 |
| Top Carton  Corner | No Insulation | 5 | 111 | 107 | 109 | 110 | 109 |
| | Insulation | 13 | 114 | 110 | 112 | 113 | 112 |
| Middle | No Insulation | 7 | 111 | 107 | 109 | 110 | 109 |
| | Insulation | 11 | 112 | 108 | 109 | 111 | 110 |
| | Empty Case | 9 | 110 | 106 | 107 | 108 | 108 |

## C.   Tray Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 * | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 104 | 102 | 105 | 107 | 105 |
| Roof Air | | 16 | 112 | 107 | 111 | 108 | 110 |
| Top Carton  Corner | No Insulation | 17 | 109 | 105 | 107 | 106 | 107 |
| | Insulation | 25 | 111 | 107 | 110 | 108 | 109 |
| Middle | No Insulation | 19 | 111 | 106 | 108 | 105 | 108 |
| | Insulation | 23 | 102 | 103 | 105 | 103 | 103 |
| | Empty Case | 21 | 109 | 105 | 106 | 104 | 106 |

* Had solar shield in 1995

# Table 8. Standard Deviation of All Temperatures (°F), Hottest Days, 1992-1995

## A. MRE Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 9.2 | 11.4 | 12.4 | 13.3 | 11.6 |
| Roof Air | | 28 | 17.8 | 16.5 | 19.5 | 19.5 | 18.3 |
| Top Carton Corner | No Insulation | 29 | 3.8 | 3.8 | 4.2 | 4.4 | 4.0 |
| | Insulation | 37 | 2.6 | 2.4 | 2.5 | 2.7 | 2.6 |
| Middle | No Insulation | 31 | 4.3 | 3.9 | 4.5 | 4.4 | 4.3 |
| | Insulation | 35 | 2.4 | 2.3 | 2.4 | 2.6 | 2.4 |
| | Empty Case | 33 | 2.3 | 2.2 | 2.0 | 2.4 | 2.2 |

## B. B Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 9.2 | 11.4 | 12.4 | 13.3 | 11.6 |
| Roof Air | | 4 | 20.3 | 18.0 | 21.9 | 20.7 | 20.2 |
| Top Carton Corner | No Insulation | 5 | 5.2 | 4.7 | 5.4 | 5.5 | 5.2 |
| | Insulation | 13 | 5.3 | 5.2 | 5.9 | 6.1 | 5.6 |
| Middle | No Insulation | 7 | 3.2 | 2.8 | 3.2 | 3.1 | 3.1 |
| | Insulation | 11 | 3.1 | 2.7 | 2.9 | 3.1 | 2.9 |
| | Empty Case | 9 | 1.2 | 1.0 | 1.3 | 1.2 | 1.2 |

## C. Tray Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 * | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 9.2 | 11.4 | 12.4 | 13.3 | 11.6 |
| Roof Air | | 16 | 16.5 | 15.3 | 18.1 | 13.3 | 15.8 |
| Top Carton Corner | No Insulation | 17 | 5.7 | 5.4 | 5.9 | 5.1 | 5.5 |
| | Insulation | 25 | 2.6 | 2.6 | 2.7 | 2.4 | 2.6 |
| Middle | No Insulation | 19 | 7.0 | 6.5 | 7.3 | 5.5 | 6.6 |
| | Insulation | 23 | 12.5 | 1.8 | 1.9 | 1.7 | 4.5 |
| | Empty Case | 21 | 2.2 | 2.1 | 2.2 | 1.9 | 2.1 |

* Had solar shield in 1995

# Table 9. Absolute Maximum Temperatures (°F) Hottest Days 1992-1995

## A. MRE Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 117 | 119 | 120 | 127 | 121 |
| Roof Air | | 28 | 144 | 137 | 137 | 145 | 141 |
| Top Cart  Corner | No Insulation | 29 | 115 | 112 | 114 | 116 | 114 |
| | Insulation | 37 | 114 | 110 | 112 | 113 | 112 |
| Middle | No Insulation | 31 | 116 | 112 | 115 | 116 | 115 |
| | Insulation | 35 | 111 | 107 | 108 | 110 | 109 |
| | Empty Case | 33 | 112 | 107 | 109 | 111 | 110 |

## B. B Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 117 | 119 | 120 | 127 | 121 |
| Roof Air | | 4 | 151 | 142 | 144 | 146 | 146 |
| Top Cart  Corner | No Insulation | 5 | 119 | 114 | 117 | 118 | 117 |
| | Insulation | 13 | 122 | 118 | 120 | 122 | 120 |
| Middle | No Insulation | 7 | 116 | 111 | 114 | 115 | 114 |
| | Insulation | 11 | 117 | 112 | 114 | 115 | 115 |
| | Empty Case | 9 | 112 | 107 | 109 | 110 | 109 |

## C. Tray Ration Van

| Locations | | Thermocouple | 1992 | 1993 | 1994 | 1995 * | Yearly Mean |
|---|---|---|---|---|---|---|---|
| Outside Ambient | | 2 | 117 | 119 | 120 | 127 | 121 |
| Roof Air | | 16 | 142 | 134 | 135 | 128 | 135 |
| Top Cart  Corner | No Insulation | 17 | 118 | 114 | 116 | 114 | 115 |
| | Insulation | 25 | 114 | 111 | 113 | 111 | 112 |
| Middle | No Insulation | 19 | 122 | 117 | 119 | 113 | 118 |
| | Insulation | 23 | 117 | 106 | 107 | 106 | 109 |
| | Empty Case | 21 | 113 | 108 | 110 | 107 | 109 |

* Had solar shield in 1995

# Table 10. Effect of Insulation and Empty Cases on Case Air Temperature, 1 Aug 1993

### A. Temperatures (°F) of hottest day:  MRE Container Vans

| Day 213 | Outside Ambient | Inside Roof Air | Top Cases | | | | Empty Boxes |
| | | | Corner | | Middle | | |
| | | | No Insul | Insul | No Insul | Insul | |
|---|---|---|---|---|---|---|---|
| Thermocoupl | 2 | 28 | 29 | 37 | 31 | 35 | 33 |
| Mean (°F) | 102 | 108 | 106 | 107 | 106 | 103 | 104 |
| S.D. | 11.4 | 16.5 | 3.8 | 2.4 | 3.9 | 2.3 | 2.2 |
| Maximum (°F) | 119 | 137 | 112 | 110 | 112 | 107 | 107 |

### B.  Temperatures (°F) of hottest day:  B Ration Container Vans

| Day 213 | Outside Ambient | Inside Roof Air | Top Cases | | | | Empty Boxes |
| | | | Corner | | Middle | | |
| | | | No Insul | Insul | No Insul | Insul | |
|---|---|---|---|---|---|---|---|
| Thermocoupl | 2 | 4 | 5 | 13 | 7 | 11 | 9 |
| Mean (°F) | 102 | 110 | 107 | 110 | 107 | 108 | 106 |
| S.D. | 11.4 | 18.0 | 4.7 | 5.2 | 2.8 | 2.7 | 1.0 |
| Maximum (°F) | 119 | 142 | 114 | 118 | 111 | 112 | 107 |

### C. Temperatures (°F) of hottest day:  Tray Ration Container Vans

| Day 213 | Outside Ambient | Inside Roof Air | Top Cases | | | | Empty Boxes |
| | | | Corner | | Middle | | |
| | | | No Insul | Insul | No Insul | Insul | |
|---|---|---|---|---|---|---|---|
| Thermocoupl | 2 | 16 | 17 | 25 | 19 | 23 | 21 |
| Mean (°F) | 102 | 107 | 105 | 107 | 106 | 103 | 105 |
| S.D. | 11.4 | 15.3 | 5.4 | 2.6 | 6.5 | 1.8 | 2.1 |
| Maximum (°F) | 119 | 134 | 114 | 111 | 117 | 106 | 108 |

# Table 11. Effect of Insulation and Empty Cases on Case Air Temperature, 31 July 1993

## Temperatures (°F) of second hottest day:  MRE Container Vans

| Day 212 | Outside Ambient | Inside Roof Air | Top Cases | | | | Empty Boxes |
|---|---|---|---|---|---|---|---|
| | | | Corner No Insul | Insul | Middle No Insul | Insul | |
| Thermocoup | 2 | 28 | 29 | 37 | 31 | 35 | 33 |
| Mean | 100 | 108 | 105 | 105 | 105 | 102 | 103 |
| S.D. | 10.9 | 17.8 | 4.1 | 2.7 | 4.2 | 2.5 | 2.3 |
| Max. | 115 | 135 | 111 | 109 | 111 | 106 | 106 |

## Temperatures (°F) of second hottest day:  B Ration Container Vans

| Day 212 | Outside Ambient | Inside Roof Air | Top Cases | | | | Empty Boxes |
|---|---|---|---|---|---|---|---|
| | | | Corner No Insul | Insul | Middle No Insul | Insul | |
| Thermocoup | 2 | 4 | 5 | 13 | 7 | 11 | 9 |
| Mean | 100 | 110 | 106 | 109 | 106 | 107 | 104 |
| S.D. | 10.9 | 19.7 | 5.2 | 5.8 | 3.2 | 3.1 | 1.2 |
| Max. | 115 | 140 | 114 | 118 | 111 | 111 | 106 |

## Temperatures (°F) of second hottest day:  Tray Ration Container Vans

| Day 212 | Outside Ambient | Inside Roof Air | Top Cases | | | | Empty Boxes |
|---|---|---|---|---|---|---|---|
| | | | Corner No Insul | Insul | Middle No Insul | Insul | |
| Thermocoup | 2 | 16 | 17 | 25 | 19 | 23 | 21 |
| Mean | 100 | 107 | 104 | 105 | 105 | 102 | 104 |
| S.D. | 10.9 | 16.5 | 5.9 | 2.8 | 7.2 | 2 | 2.4 |
| Max. | 115 | 132 | 114 | 109 | 118 | 105 | 108 |

**Table 12. Changes in Maximum Temperatures (°F), Hottest Day, 1994-1995, MRE Ration Van, B Ration Van, vs the T Ration Van with Solar Shield in 1995**

### A. MRE Ration Van

| Locations | | | 1994 | 1995 | Change 1995-1994 |
|---|---|---|---|---|---|
| Outside Ambient | | | 120.00 | 127.00 | 7 |
| Roof Air | | | 137.00 | 145.00 | 8 |
| Top Carton Corner | | No Insulation | 114.00 | 116.00 | 2 |
| | | Insulation | 112.00 | 113.00 | 1 |
| | Middle | No Insulation | 115.00 | 116.00 | 1 |
| | | Empty Cases | 109.00 | 111.00 | 2 |

### B. B Ration Van

| Locations | | | 1994 | 1995 | Change 1995-1994 |
|---|---|---|---|---|---|
| Outside Ambient | | | 120.00 | 127.00 | 7 |
| Roof Air | | | 144.00 | 146.00 | 2 |
| Top Carton Corner | | No Insulation | 117.00 | 118.00 | 1 |
| | | Insulation | 120.00 | 122.00 | 2 |
| | Middle | No Insulation | 114.00 | 115.00 | 1 |
| | | Empty Cases | 109.00 | 110.00 | 1 |

### C. T Ration Van

| Locations | | | 1994 | 1995 * | Change 1995-1994 |
|---|---|---|---|---|---|
| Outside Ambient | | | 120.00 | 127.00 | 7 |
| Roof Air | | | 135.00 | 128.00 | -7 |
| Top Carton Corner | | No Insulation | 116.00 | 114.00 | -2 |
| | | Insulation | 113.00 | 111.00 | -2 |
| | Middle | No Insulation | 119.00 | 113.00 | -6 |
| | | Empty Cases | 110.00 | 107.00 | -3 |

* with a solar shield

**Table 13.  Regression Analysis.  Monthly Mean Temperatures (°F) of Top Middle Case Air vs Ambient Air, 1992-1993**

|      | Ch. 31 Mean | Ch. 2 Mean | Difference | Ch. 31 vs Ch. 2 | | |
|------|-------------|------------|------------|-----------------|--------|-------|
|      |             |            |            | Regression Output: | | |
| Jul. | 100 | 93 | 7.10 | Constant | | 4.681 |
| Aug. | 102 | 94 | 7.01 | Std Err of Y Est | | 1.533 |
| Sep. | 100 | 90 | 9.80 | R Squared | | 0.992 |
| Oct. | 89 | 78 | 10.87 | No. of Observations | | 12 |
| Nov. | 68 | 59 | 8.94 | Degrees of Freedom | | 10 |
| Dec. | 57 | 52 | 5.42 | | | |
| Jan. | 60 | 55 | 5.52 | X Coefficient(s) | 1.040 | |
| Feb. | 65 | 58 | 6.82 | Std Err of Coef. | 0.030 | |
| Mar. | 75 | 68 | 7.74 | | | |
| Apr. | 83 | 76 | 7.43 | | | |
| May. | 92 | 84 | 7.66 | | | |
| Jun. | 91 | 83 | 7.40 | | | |

**Table 14. Regression Analysis.  Monthly Mean Temperatures (°F) of Top Middle Case Air vs Ambient Air, 1995**

| Month | Channel 2 | Channel 31 | Regression Output: | | |
|---|---|---|---|---|---|
| January | 56 | 61 | | | |
| February | 65 | 73 | Constant | | 5.538174462 |
| March | 67 | 75 | Std Err of Y Est | | 1.093875212 |
| April | 72 | 78 | R Squared | | 0.9954 |
| May | 78 | 85 | No. of Observations | | 12 |
| June | 89 | 95 | Degrees of Freedom | | 10 |
| July | 97 | 104 | | | |
| August | 99 | 107 | X Coefficient(s) | 1.021 | |
| September | 93 | 102 | Std Err of Coef. | 0.022 | |
| October | 78 | 86 | | | |
| November | 68 | 77 | | | |
| December | 57 | 64 | | | |

## Table 15. Effective Mean Temperatures (°F) and Expected Shelf Life for Most Critical Case. MRE Van. 1992-1993 and 1995. Arrhenius Computation of Shelf Life (Months) Where 80°F = 36 (Months) at Relative Rate =1

| Length of Storage<br><br>s= Summer, w=Winter, y=Year | | 12y | 6s | 3s | 1s | 6w | 3w | 1w | Mean<br>-12 Mos.<br>Storage | Mean<br>-12 Mos.<br>Ambient |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **1992-1993** | | | | | | |
| Maillard | Eff. Mn. Temp | 90.4 | 97.8 | 102.2 | 103.8 | 73.0 | 62.1 | 58.0 | 82 | 74.30 |
| Browning | Rel. Rate | 2.14 | 3.74 | 5.16 | 5.80 | 0.54 | 0.22 | 0.16 | | |
| 25,400 cal | Shelf Life<br>at EMT | 16.8 | 9.6 | 7.0 | 6.2 | 66.7 | 163.6 | 225.0 | | |
| | | | | **1995** | | | | | | |
| Maillard | Eff. Mn. Temp | 92.7 | 100.2 | 105.6 | 108.0 | 74.2 | 68.3 | 62.0 | 84 | 77.00 |
| Browning | Rel. Rate | 2.61 | 4.62 | 6.90 | 8.25 | 0.59 | 0.36 | 0.21 | | |
| 26,000 cal | Shelf Life<br>at EMT | 13.8 | 7.8 | 5.2 | 4.4 | 61.0 | 100.0 | 171.4 | | |

**Table 16.  Projected Shelf Life of MRE Rations at Temperatures from 80° to 100°F (27° to 38°C)**

| Mean temperature (°F) | Projected shelf life (months) |
| --- | --- |
| 80 | 34 |
| 85 | 22 |
| 90 | 15 |
| 95 | 10 |
| 100 | 6 |

**Table 17. Mean Scores: Technical Panel Evaluation of Entrees Stored at Yuma Proving Ground vs Constant Temperature Scores at 40 °F**

| Entree | | Appearance | Odor | Flavor | Texture | Overall Quality |
|---|---|---|---|---|---|---|
| Spaghetti with Meat Sauce | 40°F Storage | 6.7 * | 6.4 | 6.4 | 5.8 | 6.2 |
| | Yuma 1 Year | 6.7 | 6.1 | 6.1 | 5.5 | 5.9 |
| | Yuma 2 Years | 6.3 | 5.9 | 5.8 | 5.3 | 5.5 |
| | Yuma 3 Years | 6.8 | 6.4 | 6.2 | 5.6 | 5.9 |
| Corned Beef Hash | 40°F Storage | 6.3 | 6.3 | 6.5 | 6.6 | 6.4 |
| | Yuma 1 Year | 6.3 | 6.3 | 6.3 | 6.6 | 6.3 |
| | Yuma 2 Years | 6.1 | 6.3 | 6.2 | 6.3 | 6.1 |
| | Yuma 3 Years | 6.5 | 5.9 | 5.8 | 6.4 | 5.6 |
| Chicken with Rice | 40°F Storage | 5.6 | 6.1 | 5.9 | 5.4 | 5.7 |
| | Yuma 1 Year | 5.9 | 6.1 | 5.9 | 5.5 | 5.8 |
| | Yuma 2 Years | 5.9 | 5.8 | 5.6 | 5.4 | 5.5 |
| | Yuma 3 Years | 5.2 | 5.6 | 5.4 | 5.1 | 4.9 |
| Omelet with Ham | 40°F Storage | 6.1 [A] | 6.5 [A] | 6.3 [A] | 6.3 [A] | 6.3 [A] |
| | Yuma 1 Year | 5.6 [A] | 6.4 [A] | 5.8 [B] | 6.3 [A] | 5.6 [B] |
| | Yuma 2 Years | 5.3 [A] | 6.3 [A] | 5.1 [B] | 5.8 [A] | 4.9 [B] |
| | Yuma 3 Years | 4.2 [B] | 5.1 [B] | 4.2 [B] | 5.0 [B] | 4.0 [B] |
| Chicken Stew | 40°F Storage | 6.7 [A] | 6.7 [A] | 6.8 [A] | 6.3 [A] | 6.6 [A] |
| | Yuma 1 Year | 5.9 [A] | 6.1 [A] | 5.6 [B] | 6.1 [A] | 5.4 [B] |
| | Yuma 2 Years | 5.6 [B] | 6.2 [A] | 5.5 [B] | 5.8 [A] | 5.4 [B] |
| | Yuma 3 Years | 5.5 [B] | 5.1 [B] | 4.6 [B] | 5.2 [B] | 4.7 [B] |
| Tuna with Noodles | 40°F Storage | 6.0 [A] | 5.6 [A] | 5.5 [A] | 5.8 [A] | 5.4 [A] |
| | Yuma 1 Year | 5.6 [A] | 5.6 [A] | 5.3 [A] | 5.6 [A] | 5.4 [A] |
| | Yuma 2 Years | 5.5 [A] | 4.8 [A] | 4.4 [A] | 5.4 [A] | 4.5 [B] |
| | Yuma 3 Years | 4.7 [B] | 4.2 [B] | 3.4 [B] | 4.6 [B] | 3.3 [B] |
| Beef Stew | 40°F Storage | 6.9 | 6.9 | 6.8 | 6.8 | 6.6 |
| | Yuma 1 Year | 6.4 | 6.1 | 6.1 | 6.3 | 6.0 |
| | Yuma 2 Years | 6.4 | 6.0 | 6.0 | 6.3 | 5.8 |
| | Yuma 3 Years | 7.2 | 7.0 | 6.6 | 6.6 | 6.6 |
| Chicken a la King | 40°F Storage | 6.5 [A] | 6.4 [A] | 6.4 [A] | 6.0 [A] | 6.2 [A] |
| | Yuma 1 Year | 5.3 [B] | 5.3 [B] | 5.3 [B] | 5.2 [A] | 4.9 [B] |
| | Yuma 2 Years | 5.6 [A] | 5.3 [B] | 5.4 [B] | 5.4 [A] | 5.3 [B] |
| | Yuma 3 Years | 5.0 [B] | 5.1 [B] | 4.1 [B] | 4.9 [B] | 4.3 [B] |
| Potatoes au Gratin | 40°F Storage | 6.6 [A] | 6.4 | 6.6 | 6.6 | 6.6 [A] |
| | Yuma 1 Year | 5.8 [B] | 6.1 | 6.0 | 6.3 | 5.9 [B] |
| | Yuma 2 Years | 5.6 [B] | 5.9 | 5.9 | 6.4 | 6.0 [B] |
| | Yuma 3 Years | ** | ** | ** | ** | ** |

*(Continued)*

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**Table 17.   Mean Scores:   Technical Panel Evaluation of Entrees Stored at Yuma Proving Ground vs Constant Temperature Scores at 40° F (Continued)**

| | | Appearance | Odor | Flavor | Texture | Overall Quality | Entree |
|---|---|---|---|---|---|---|---|
| Meatballs with Tomato Sauce | 40°F Storage | 6.8 | 6.8 | 6.6 | 6.6$^A$ | 6.6$^A$ | |
| | Yuma 1 Year | 6.5 | 6.8 | 6.2 | 6.1$^A$ | 6.6$^A$ | |
| | Yuma 2 Years | 6.8 | 6.7 | 6.3 | 6.3$^A$ | 6.3$^A$ | |
| | Yuma 3 Years | 6.6 | 6.2 | 5.9 | 5.7$^B$ | 5.8$^B$ | |
| Pork with Rice | 40°F Storage | 6.6$^A$ | 6.5 | 6.7$^A$ | 6.4$^A$ | 6.4$^A$ | |
| | Yuma 1 Year | 6.7$^A$ | 6.6 | 6.4$^A$ | 6.2$^A$ | 6.3$^A$ | |
| | Yuma 2 Years | 6.6$^A$ | 6.3 | 6.0$^A$ | 5.7$^A$ | 5.8$^A$ | |
| | Yuma 3 Years | 5.8$^B$ | 5.9 | 5.6$^B$ | 5.5$^B$ | 5.2$^B$ | |
| Ham Slices | 40°F Storage | 6.8 | 6.7 | 6.9$^A$ | 6.7 | 6.8$^A$ | |
| | Yuma 1 Year | 6.7 | 6.7 | 6.7$^A$ | 6.4 | 6.3$^A$ | |
| | Yuma 2 Years | 6.6 | 6.4 | 6.5$^A$ | 6.0 | 6.1$^B$ | |
| | Yuma 3 Years | 6.3 | 6.0 | 5.9$^B$ | 6.1 | 5.9$^B$ | |

\*   Score values with no letter following are not statistically different from 40° F samples; scores followed by different letters are significantly different, $p = \leq .05$.

\*\*   Not conducted.

## Table 18. Comparison of Extreme Day Temperatures* (°F) in Boxcars and Storage Dumps in the 1950s with Container Vans in 1992-1995

| Location | 1950s Boxcars | | 1950s Dumps | | 1992-5 Container Vans | |
|---|---|---|---|---|---|---|
| | Maximum | Mean | Maximum | Mean | Maximum | Mean |
| Ambient Air | 112 | 95 | 112 | 100 | 127 | 107 |
| Roof Air | 151 | 114 | 159† | 119† | 151 | 115 |
| Top Center** Carton (Interior) | 118 | 106 | 118 | 108 | 122‡‡ | 111 |

\*   Absolute extremes - not necessarily on the same day or in same container
\*\*   Center in boxcar and storage dump, south wall, center, in container van
†   Under surface of dark, olive-drab 8 oz. tarpaulin cover
‡‡   Possible defective positioning of thermocouple in contact with case surface

# VII. REFERENCES

1. Porter, W.L., Shaw, C.P., and Wright, Bruce, Occurrence and Effects of High Temperature Stress in Rations Stored in Container Vans: A Comparison with Storage Studies in the 1950s, Natick Technical Report NATICK/TR-93/027, April 1993, AD A264 398.

2. Porter, W.L., and Greenwald, A., The Analysis of High Temperature Occurrences at Selected Internal and Surface Locations in Food Storage Dumps and Isolated Small Cartons at Yuma, AZ., Natick Technical Report 71-59-FL and 71-59-ES, January 1971, AD 736 359.

3. Porter, W. L., and Greenwald, A., Comparison of the Occurrence of High Temperatures in Air and Food in Boxcars in Desert and Humid Subtropical Climates--Yuma, AZ and Cameron Station, VA., Natick Technical Report 71-55-FL and 71-55-ES., January 1971, AD 732 845.

4. Porter, W. L., and Greenwald, A., Temperature Distribution and Effects of Insulation and Night-Time Ventilation in an Army Warehouse, Natick Technical Report 71-49-FL and 71-49-ES, January 1971, AD 728 821.

5. Riordan, Pauline, Weather Extremes Around the World, ETL-TR-74-5 (Revision of NLABS Report TR-70-45-ES), U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA 22060, April 1974.

6. Krause, Paul F., A Digest of High-Temperature Storage Literature, ETL-0152, U.S. Army Corps of Engineers, Engineer Topographic Laboratories, Fort Belvoir, VA 22060, July 1978.

7. Norman, E.J., and Gaither, R.M., Review of Army Food Related Operations in Hot Desert Environments NATICK/TR-91/008, February 1991, AD A232 868.

8. Corps of Engineers, Analogs of Yuma Climate in the Middle East, Yuma Analogs No. 1, Research Study Report for the Environmental Analogs Project (8-97-10-002), Waterways Experiment Station, Vicksburg, MS, March 1954.

9. Labuza, T. P., Shelf-Life Dating of Foods, Food and Nutrition Press, Inc., Westport, CN 06880, 1982, p. 64.

10. Hicks, E.W., Notes on the Estimation of the Effect of Diurnal Temperature Fluctuations on Reaction Rates in Stored Foodstuffs and Other Materials. J. of the Council for Scientific and Industrial Research, 17, 2, May 1944, Commonwealth of Australia, Melbourne.

11. LifeLines Technology, Inc., Morris Plains, NJ.

12. Shaw, C. P., Kluter, R. A., Morse, M., Engell, D. The Effects of Fluctuating Temperature Storage on the Acceptability of Meal, Ready-to-Eat Components, Natick Technical Report NATICK/TR-97/008, February 1997, AD A321 304.

# APPENDICES

A. Appendix Tables A-1 to A-10: 1995 Temperatures

B. Appendix Tables B-1 to B-6: 1994 Temperatures

# APPENDIX A

**TABLE A-1.**      MEAN TEMPERATURES (°F) 1995

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP* | OCT | NOV | DEC | YEARLY MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 56 | 65 | 67 | 72 | 78 | 89 | 98 | 100 | 94 | 78 | 68 | 57 | 77 |
| 2 | 56 | 65 | 67 | 72 | 78 | 89 | 97 | 99 | 93 | 78 | 68 | 57 | 77 |
| 4 | 60 | 72 | 75 | 80 | 88 | 99 | 107 | 109 | 101 | 83 | 74 | 61 | 84 |
| 5 | 60 | 72 | 74 | 78 | 85 | 95 | 104 | 107 | 101 | 84 | 75 | 63 | 83 |
| 7 | 62 | 74 | 76 | 79 | 86 | 96 | 105 | 108 | 103 | 87 | 78 | 66 | 85 |
| 8 | 62 | 74 | 76 | 78 | 85 | 95 | 103 | 107 | 103 | 87 | 78 | 66 | 85 |
| 9 | 63 | 75 | 77 | 79 | 86 | 96 | 104 | 108 | 104 | 89 | 80 | 67 | 86 |
| 11 | 65 | 77 | 79 | 81 | 88 | 97 | 105 | 109 | 106 | 91 | 83 | 70 | 88 |
| 13 | 64 | 76 | 79 | 82 | 89 | 98 | 106 | 109 | 105 | 90 | 80 | 68 | 87 |
| 16 | 59 | 70 | 74 | 79 | 82 | 93 | 101 | 103 | 97 | 81 | 71 | 60 | 81 |
| 17 | 60 | 71 | 73 | 77 | 81 | 91 | 99 | 102 | 97 | 81 | 72 | 60 | 80 |
| 19 | 62 | 73 | 76 | 78 | 81 | 91 | 100 | 103 | 98 | 82 | 73 | 61 | 82 |
| 20 | 63 | 74 | 76 | 77 | 81 | 90 | 99 | 103 | 99 | 83 | 74 | 62 | 82 |
| 21 | ** | 76 | 78 | 79 | 81 | 90 | 99 | 103 | 99 | 84 | 75 | 64 | 77 |
| 23 | 64 | 75 | 77 | 78 | 81 | 90 | 99 | 103 | 99 | 85 | 75 | 64 | 82 |
| 25 | 63 | 75 | 78 | 81 | 86 | 95 | 103 | 107 | 103 | 88 | 77 | 65 | 85 |
| 28 | 60 | 71 | 74 | 79 | 86 | 97 | 105 | 108 | 101 | 84 | 75 | 62 | 84 |
| 29 | 60 | 71 | 74 | 77 | 84 | 95 | 104 | 106 | 101 | 85 | 76 | 63 | 83 |
| 31 | 61 | 73 | 75 | 78 | 85 | 95 | 104 | 107 | 102 | 86 | 77 | 64 | 84 |
| 32 | 61 | 72 | 75 | 77 | 84 | 94 | 103 | 107 | 102 | 86 | 77 | 65 | 84 |
| 33 | 60 | 72 | 74 | 75 | 84 | 93 | 102 | 106 | 102 | 86 | 77 | 65 | 83 |
| 35 | 61 | 72 | 74 | 76 | 83 | 93 | 101 | 106 | 102 | 86 | 77 | 65 | 83 |
| 37 | 61 | 73 | 75 | 78 | 85 | 94 | 103 | 106 | 102 | 86 | 77 | 65 | 84 |

**TABLE A-2.**      EFFECTIVE MEAN TEMPERATURES (°F) 1995
                 ACTIVATION ENERGY = 26000 CAL/MOLE

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY EFFECTIVE MEAN | INCREASE FROM MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 59 | 71 | 73 | 79 | 84 | 96 | 102 | 103 | 98 | 85 | 75 | 63 | 89 | 13 |
| 2 | 58 | 70 | 72 | 78 | 84 | 95 | 102 | 102 | 97 | 84 | 73 | 62 | 89 | 12 |
| 4 | 72 | 89 | 91 | 98 | 104 | 115 | 120 | 121 | 115 | 101 | 90 | 76 | 107 | 23 |
| 5 | 62 | 74 | 76 | 81 | 87 | 98 | 105 | 108 | 103 | 87 | 77 | 65 | 93 | 9 |
| 7 | 63 | 75 | 77 | 81 | 87 | 98 | 105 | 109 | 104 | 88 | 79 | 67 | 93 | 8 |
| 8 | 63 | 75 | 77 | 80 | 86 | 96 | 104 | 108 | 104 | 88 | 79 | 68 | 92 | 8 |
| 9 | 64 | 75 | 78 | 80 | 87 | 96 | 104 | 108 | 105 | 89 | 80 | 69 | 93 | 8 |
| 11 | 66 | 78 | 80 | 83 | 89 | 98 | 106 | 110 | 107 | 93 | 84 | 72 | 95 | 7 |
| 13 | 66 | 79 | 81 | 85 | 91 | 100 | 107 | 111 | 107 | 92 | 82 | 71 | 96 | 9 |
| 16 | 68 | 83 | 85 | 91 | 89 | 100 | 106 | 107 | 102 | 87 | 76 | 65 | 94 | 13 |
| 17 | 62 | 74 | 76 | 80 | 83 | 93 | 100 | 103 | 98 | 83 | 73 | 62 | 88 | 8 |
| 19 | 64 | 76 | 78 | 82 | 83 | 93 | 101 | 104 | 99 | 84 | 74 | 63 | 89 | 8 |
| 20 | 63 | 74 | 77 | 79 | 81 | 90 | 99 | 103 | 99 | 84 | 74 | 64 | 88 | 6 |
| 21 | 52 | 77 | 78 | 80 | 82 | 91 | 99 | 103 | 99 | 85 | 75 | 65 | 89 | 11 |
| 23 | 64 | 75 | 77 | 79 | 82 | 91 | 99 | 103 | 100 | 85 | 75 | 65 | 89 | 6 |
| 25 | 64 | 75 | 79 | 82 | 87 | 96 | 104 | 107 | 103 | 88 | 77 | 66 | 92 | 7 |
| 28 | 71 | 87 | 88 | 94 | 100 | 111 | 117 | 118 | 113 | 101 | 90 | 77 | 104 | 20 |
| 29 | 61 | 73 | 75 | 80 | 86 | 97 | 105 | 107 | 102 | 86 | 77 | 65 | 92 | 9 |
| 31 | 62 | 74 | 76 | 80 | 87 | 97 | 105 | 108 | 104 | 87 | 78 | 66 | 93 | 9 |
| 32 | 61 | 72 | 76 | 78 | 85 | 95 | 103 | 107 | 103 | 87 | 77 | 66 | 92 | 8 |
| 33 | 61 | 73 | 76 | 85 | 93 | 101 | 102 | 107 | 103 | 87 | 78 | 67 | 93 | 10 |
| 35 | 61 | 72 | 75 | 78 | 84 | 94 | 102 | 106 | 102 | 87 | 78 | 67 | 91 | 8 |
| 37 | 62 | 74 | 76 | 80 | 86 | 96 | 103 | 107 | 103 | 87 | 77 | 66 | 92 | 8 |

\* incomplete data day 262,   \*\* significant data lost

# TABLE A-3. TEMPERATURE STANDARD DEVIATIONS (°F) 1995

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP* | OCT | NOV | DEC | YEARLY MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 11 | 12 | 13 | 13 | 15 | 12 | 10 | 12 | 14 | 13 | 12 | 12 |
| 2 | 8 | 10 | 11 | 12 | 12 | 14 | 11 | 10 | 11 | 13 | 11 | 11 | 11 |
| 4 | 15 | 20 | 20 | 22 | 22 | 23 | 21 | 19 | 20 | 21 | 20 | 18 | 20 |
| 5 | 5 | 7 | 7 | 9 | 8 | 8 | 6 | 6 | 7 | 8 | 6 | 8 | 7 |
| 7 | 4 | 5 | 6 | 7 | 6 | 7 | 4 | 4 | 5 | 6 | 4 | 7 | 6 |
| 8 | 3 | 4 | 5 | 7 | 6 | 6 | 4 | 4 | 5 | 5 | 4 | 6 | 5 |
| 9 | 4 | 4 | 4 | 6 | 4 | 5 | 3 | 3 | 4 | 4 | 2 | 6 | 4 |
| 11 | 5 | 6 | 5 | 7 | 5 | 6 | 4 | 4 | 5 | 6 | 5 | 7 | 5 |
| 13 | 6 | 8 | 7 | 9 | 8 | 8 | 6 | 6 | 7 | 8 | 7 | 8 | 7 |
| 16 | 13 | 17 | 17 | 18 | 13 | 14 | 12 | 11 | 12 | 13 | 11 | 11 | 14 |
| 17 | 6 | 8 | 8 | 9 | 7 | 8 | 5 | 5 | 6 | 7 | 5 | 7 | 7 |
| 19 | 7 | 9 | 8 | 9 | 7 | 7 | 5 | 5 | 6 | 7 | 5 | 7 | 7 |
| 20 | 3 | 4 | 4 | 5 | 4 | 5 | 3 | 3 | 4 | 4 | 2 | 5 | 4 |
| 21 | ** | 5 | 5 | 6 | 5 | 5 | 3 | 3 | 4 | 4 | 3 | 5 | 4 |
| 23 | 3 | 4 | 4 | 5 | 4 | 5 | 3 | 3 | 4 | 4 | 2 | 5 | 4 |
| 25 | 3 | 4 | 4 | 6 | 4 | 5 | 3 | 4 | 4 | 5 | 3 | 5 | 4 |
| 28 | 15 | 19 | 19 | 20 | 19 | 21 | 19 | 18 | 19 | 21 | 19 | 18 | 19 |
| 29 | 4 | 5 | 6 | 8 | 7 | 7 | 5 | 5 | 6 | 7 | 5 | 7 | 6 |
| 31 | 4 | 6 | 6 | 8 | 7 | 7 | 5 | 5 | 6 | 7 | 5 | 7 | 6 |
| 32 | 2 | 4 | 4 | 5 | 5 | 5 | 3 | 3 | 4 | 5 | 3 | 6 | 4 |
| 33 | 3 | 5 | 8 | 15 | 15 | 15 | 3 | 3 | 5 | 5 | 4 | 6 | 7 |
| 35 | 3 | 4 | 5 | 6 | 5 | 5 | 3 | 3 | 5 | 5 | 4 | 6 | 5 |
| 37 | 4 | 5 | 5 | 7 | 6 | 6 | 4 | 4 | 5 | 5 | 4 | 6 | 5 |

# TABLE A-4. NUMBER OF DATA POINTS 1995

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP* | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 2 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 4 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 5 | 744 | 672 | 744 | 721 | 744 | 718 | 744 | 744 | 714 | 744 | 720 | 744 |
| 7 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 8 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 9 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 11 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 13 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 16 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 17 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 19 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 20 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 21 | 268 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 713 | 744 | 720 | 744 |
| 23 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 25 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 28 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 29 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 31 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 32 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 33 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 35 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |
| 37 | 744 | 672 | 744 | 721 | 744 | 719 | 744 | 744 | 714 | 744 | 720 | 744 |

* incomplete data day 262, ** significant data lost

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## TABLE A-5　　ABSOLUTE MAXIMUM TEMPERATURE (°F) 1995

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY MEAN | YEARLY ABSOLUTE MAXIMUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 80 | 91 | 96 | 101 | 108 | 118 | 128 | 121 | 119 | 109 | 94 | 87 | 104 | 128 |
| 2 | 75 | 90 | 94 | 98 | 106 | 115 | 127 | 119 | 116 | 107 | 92 | 86 | 102 | 127 |
| 4 | 110 | 122 | 129 | 134 | 141 | 146 | 152 | 150 | 148 | 137 | 122 | 110 | 133 | 152 |
| 5 | 79 | 90 | 95 | 99 | 104 | 112 | 118 | 119 | 119 | 103 | 89 | 82 | 101 | 119 |
| 7 | 74 | 86 | 92 | 96 | 101 | 109 | 115 | 116 | 116 | 99 | 87 | 79 | 97 | 116 |
| 8 | 72 | 83 | 88 | 93 | 97 | 107 | 112 | 114 | 113 | 97 | 85 | 78 | 95 | 114 |
| 9 | 111 | 91 | 97 | 91 | 96 | 105 | 111 | 113 | 112 | 95 | 83 | 77 | 98 | 113 |
| 11 | 79 | 90 | 94 | 96 | 101 | 109 | 115 | 117 | 117 | 104 | 93 | 86 | 100 | 117 |
| 13 | 84 | 94 | 100 | 102 | 106 | 115 | 122 | 122 | 121 | 109 | 97 | 89 | 105 | 122 |
| 16 | 100 | 110 | 120 | 126 | 113 | 122 | 128 | 126 | 123 | 111 | 96 | 89 | 114 | 128 |
| 17 | 81 | 91 | 95 | 97 | 99 | 106 | 114 | 112 | 112 | 96 | 82 | 76 | 97 | 114 |
| 19 | 85 | 95 | 100 | 101 | 98 | 106 | 113 | 114 | 113 | 99 | 85 | 78 | 99 | 114 |
| 20 | 72 | 83 | 87 | 90 | 90 | 100 | 106 | 107 | 106 | 90 | 78 | 71 | 90 | 107 |
| 21 | ** | 86 | 90 | 92 | 92 | 101 | 107 | 108 | 107 | 92 | 80 | 73 | 86 | 108 |
| 23 | 73 | 84 | 87 | 90 | 90 | 100 | 106 | 108 | 106 | 92 | 79 | 73 | 91 | 108 |
| 25 | 73 | 83 | 89 | 95 | 97 | 106 | 111 | 113 | 111 | 97 | 82 | 74 | 94 | 113 |
| 28 | 106 | 117 | 125 | 127 | 134 | 142 | 148 | 147 | 146 | 135 | 121 | 111 | 130 | 148 |
| 29 | 73 | 84 | 90 | 95 | 101 | 110 | 116 | 116 | 116 | 99 | 86 | 78 | 97 | 116 |
| 31 | 74 | 86 | 91 | 96 | 102 | 110 | 116 | 118 | 116 | 100 | 87 | 80 | 98 | 118 |
| 32 | 68 | 79 | 84 | 89 | 95 | 105 | 110 | 112 | 111 | 93 | 81 | 74 | 92 | 112 |
| 33 | 70 | 91 | 105 | 123 | 125 | 130 | 111 | 113 | 112 | 96 | 84 | 77 | 103 | 130 |
| 35 | 70 | 81 | 86 | 90 | 95 | 105 | 110 | 112 | 112 | 96 | 84 | 77 | 93 | 112 |
| 37 | 72 | 83 | 88 | 93 | 97 | 106 | 113 | 114 | 112 | 96 | 84 | 76 | 94 | 114 |


## TABLE A-6　　ABSOLUTE MINIMUM TEMPERATURE (°F) 1995

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY MEAN | YEARLY ABSOLUTE MINIMUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 36 | 43 | 39 | 46 | 51 | 58 | 67 | 78 | 63 | 46 | 43 | 33 | 50 | 33 |
| 2 | 37 | 45 | 41 | 47 | 52 | 60 | 70 | 78 | 66 | 49 | 44 | 35 | 52 | 35 |
| 4 | 37 | 45 | 42 | 48 | 53 | 61 | 71 | 79 | 66 | 50 | 46 | 36 | 53 | 36 |
| 5 | 49 | 58 | 57 | 59 | 65 | 75 | 89 | 93 | 80 | 65 | 58 | 45 | 66 | 45 |
| 7 | 53 | 64 | 63 | 64 | 70 | 81 | 94 | 97 | 86 | 72 | 64 | 50 | 71 | 50 |
| 8 | 54 | 65 | 65 | 65 | 72 | 83 | 95 | 97 | 88 | 74 | 66 | 52 | 73 | 52 |
| 9 | 56 | 66 | 70 | 59 | 76 | 87 | 98 | 100 | 93 | 79 | 71 | 51 | 75 | 51 |
| 11 | 55 | 57 | 68 | 67 | 75 | 85 | 97 | 99 | 91 | 77 | 69 | 54 | 74 | 54 |
| 13 | 53 | 63 | 62 | 63 | 69 | 79 | 92 | 95 | 85 | 71 | 63 | 49 | 70 | 49 |
| 16 | 39 | 48 | 45 | 50 | 58 | 66 | 78 | 84 | 72 | 57 | 52 | 41 | 58 | 39 |
| 17 | 48 | 57 | 56 | 58 | 63 | 74 | 88 | 90 | 79 | 64 | 58 | 46 | 65 | 46 |
| 19 | 51 | 58 | 59 | 61 | 67 | 76 | 89 | 92 | 82 | 68 | 61 | 48 | 68 | 48 |
| 20 | 56 | 64 | 68 | 67 | 72 | 81 | 94 | 96 | 88 | 74 | 67 | 52 | 73 | 52 |
| 21 | ** | 66 | 68 | 66 | 71 | 81 | 93 | 95 | 87 | 74 | 66 | 53 | 68 | 53 |
| 23 | 57 | 66 | 69 | 67 | 73 | 82 | 94 | 96 | 89 | 75 | 68 | 54 | 74 | 54 |
| 25 | 56 | 65 | 69 | 69 | 76 | 85 | 98 | 98 | 91 | 77 | 69 | 54 | 76 | 54 |
| 28 | 39 | 46 | 43 | 49 | 55 | 62 | 72 | 81 | 68 | 52 | 48 | 38 | 55 | 38 |
| 29 | 51 | 60 | 59 | 61 | 67 | 78 | 92 | 93 | 82 | 68 | 60 | 47 | 68 | 47 |
| 31 | 52 | 61 | 61 | 63 | 69 | 80 | 92 | 95 | 84 | 70 | 62 | 49 | 70 | 49 |
| 32 | 55 | 64 | 68 | 67 | 75 | 86 | 97 | 99 | 89 | 76 | 67 | 53 | 75 | 53 |
| 33 | 50 | 59 | 42 | 47 | 55 | 62 | 95 | 97 | 88 | 74 | 66 | 52 | 65 | 42 |
| 35 | 52 | 59 | 64 | 63 | 72 | 82 | 94 | 97 | 88 | 74 | 66 | 52 | 72 | 52 |
| 37 | 53 | 64 | 65 | 65 | 71 | 83 | 95 | 96 | 87 | 73 | 65 | 50 | 72 | 50 |

* incomplete data day 262,  ** significant data lost

# TABLE A-7.    MEAN MAXIMUM TEMPERATURES (°F) 1995

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY MEAN MAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 68 | 82 | 82 | 87 | 93 | 106 | 113 | 114 | 108 | 97 | 88 | 75 | 93 |
| 2 | 66 | 80 | 81 | 86 | 91 | 104 | 111 | 112 | 107 | 95 | 86 | 73 | 91 |
| 4 | 88 | 110 | 109 | 114 | 121 | 133 | 139 | 141 | 134 | 121 | 110 | 94 | 118 |
| 5 | 67 | 81 | 82 | 86 | 92 | 103 | 111 | 114 | 109 | 94 | 85 | 71 | 91 |
| 7 | 66 | 79 | 81 | 84 | 91 | 101 | 108 | 112 | 107 | 92 | 83 | 70 | 90 |
| 8 | 65 | 77 | 79 | 81 | 88 | 98 | 106 | 110 | 106 | 91 | 82 | 69 | 88 |
| 9 | 67 | 78 | 79 | 82 | 88 | 97 | 105 | 109 | 106 | 90 | 81 | 69 | 87 |
| 11 | 70 | 83 | 84 | 86 | 91 | 101 | 109 | 113 | 110 | 97 | 89 | 75 | 92 |
| 13 | 73 | 87 | 88 | 91 | 96 | 105 | 113 | 117 | 113 | 100 | 91 | 78 | 96 |
| 16 | 83 | 101 | 102 | 106 | 100 | 111 | 118 | 119 | 113 | 100 | 90 | 77 | 102 |
| 17 | 69 | 83 | 83 | 86 | 88 | 98 | 105 | 108 | 103 | 88 | 79 | 67 | 88 |
| 19 | 72 | 87 | 87 | 90 | 88 | 98 | 106 | 109 | 105 | 91 | 81 | 69 | 90 |
| 20 | 65 | 77 | 79 | 80 | 83 | 91 | 100 | 104 | 100 | 85 | 76 | 64 | 84 |
| 21 | ** | 80 | 81 | 83 | 83 | 92 | 101 | 105 | 101 | 87 | 77 | 66 | 80 |
| 23 | 66 | 78 | 80 | 81 | 83 | 92 | 100 | 104 | 101 | 87 | 77 | 66 | 85 |
| 25 | 66 | 78 | 81 | 85 | 89 | 97 | 106 | 109 | 105 | 90 | 80 | 68 | 88 |
| 28 | 86 | 107 | 105 | 109 | 115 | 128 | 134 | 137 | 131 | 120 | 110 | 95 | 115 |
| 29 | 64 | 77 | 79 | 83 | 90 | 101 | 110 | 112 | 106 | 91 | 81 | 68 | 89 |
| 31 | 66 | 79 | 82 | 84 | 91 | 102 | 109 | 113 | 108 | 92 | 83 | 70 | 90 |
| 32 | 63 | 74 | 78 | 79 | 86 | 96 | 104 | 108 | 104 | 88 | 79 | 66 | 85 |
| 33 | 64 | 76 | 83 | 100 | 110 | 114 | 105 | 109 | 105 | 90 | 81 | 69 | 92 |
| 35 | 64 | 76 | 79 | 80 | 86 | 96 | 104 | 109 | 105 | 90 | 81 | 69 | 87 |
| 37 | 65 | 77 | 80 | 82 | 86 | 98 | 106 | 109 | 105 | 90 | 80 | 68 | 87 |

# TABLE A-8.    MEAN MINIMUM TEMPERATURES (°F) 1995

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP* | OCT | NOV | DEC | YEARLY MEAN MIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 46 | 51 | 52 | 56 | 62 | 69 | 79 | 85 | 79 | 60 | 52 | 43 | 61 |
| 2 | 46 | 52 | 53 | 57 | 64 | 71 | 81 | 86 | 80 | 61 | 53 | 44 | 62 |
| 4 | 45 | 51 | 53 | 57 | 63 | 71 | 81 | 86 | 80 | 61 | 54 | 44 | 62 |
| 5 | 55 | 64 | 67 | 71 | 78 | 87 | 96 | 100 | 94 | 76 | 67 | 56 | 76 |
| 7 | 59 | 70 | 72 | 75 | 82 | 92 | 100 | 104 | 99 | 82 | 74 | 62 | 81 |
| 8 | 60 | 71 | 73 | 76 | 82 | 92 | 100 | 105 | 100 | 84 | 75 | 63 | 82 |
| 9 | 61 | 73 | 75 | 77 | 85 | 94 | 102 | 107 | 103 | 87 | 78 | 66 | 84 |
| 11 | 61 | 72 | 75 | 77 | 84 | 93 | 102 | 106 | 102 | 86 | 77 | 65 | 83 |
| 13 | 58 | 68 | 70 | 74 | 81 | 89 | 98 | 102 | 97 | 80 | 72 | 60 | 79 |
| 16 | 47 | 53 | 55 | 59 | 67 | 75 | 85 | 90 | 84 | 67 | 59 | 49 | 66 |
| 17 | 54 | 63 | 65 | 68 | 75 | 84 | 93 | 97 | 91 | 74 | 65 | 55 | 74 |
| 19 | 55 | 64 | 67 | 70 | 76 | 84 | 93 | 97 | 92 | 76 | 67 | 57 | 75 |
| 20 | 60 | 71 | 74 | 75 | 79 | 88 | 97 | 101 | 97 | 82 | 72 | 61 | 80 |
| 21 | ** | 72 | 74 | 76 | 80 | 88 | 97 | 101 | 97 | 82 | 72 | 61 | 75 |
| 23 | 61 | 72 | 74 | 76 | 80 | 88 | 97 | 101 | 98 | 83 | 73 | 62 | 80 |
| 25 | 60 | 71 | 74 | 77 | 83 | 92 | 100 | 104 | 100 | 84 | 74 | 63 | 82 |
| 28 | 46 | 52 | 54 | 58 | 64 | 72 | 81 | 87 | 81 | 63 | 56 | 46 | 63 |
| 29 | 56 | 66 | 68 | 72 | 79 | 89 | 98 | 101 | 95 | 78 | 70 | 58 | 77 |
| 31 | 57 | 67 | 69 | 73 | 80 | 89 | 98 | 102 | 97 | 79 | 71 | 59 | 78 |
| 32 | 60 | 70 | 74 | 76 | 83 | 93 | 102 | 105 | 101 | 84 | 75 | 63 | 82 |
| 33 | 58 | 68 | 66 | 58 | 66 | 77 | 99 | 104 | 99 | 83 | 74 | 62 | 76 |
| 35 | 58 | 68 | 71 | 73 | 80 | 90 | 98 | 103 | 98 | 82 | 73 | 62 | 80 |
| 37 | 58 | 69 | 72 | 75 | 82 | 91 | 100 | 103 | 99 | 82 | 73 | 61 | 80 |

* incomplete data day 262,  ** significant data lost

# TABLE A-9. RANGE BETWEEN ABSOLUTE MAXIMUM AND ABSOLUTE MINIMUM (°F)

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP* | OCT | NOV | DEC | YEARLY MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 44 | 47 | 57 | 55 | 57 | 60 | 61 | 43 | 56 | 63 | 51 | 54 | 54 |
| 2 | 38 | 45 | 53 | 51 | 54 | 55 | 57 | 41 | 50 | 58 | 48 | 50 | 50 |
| 4 | 72 | 77 | 87 | 86 | 88 | 85 | 81 | 71 | 82 | 86 | 76 | 74 | 82 |
| 5 | 30 | 31 | 39 | 39 | 39 | 37 | 29 | 27 | 38 | 38 | 31 | 37 | 35 |
| 7 | 22 | 23 | 28 | 31 | 31 | 28 | 21 | 20 | 29 | 27 | 23 | 29 | 26 |
| 8 | 18 | 19 | 23 | 27 | 26 | 24 | 17 | 17 | 25 | 23 | 19 | 26 | 22 |
| 9 | 55 | 25 | 27 | 32 | 20 | 18 | 13 | 13 | 19 | 16 | 13 | 26 | 24 |
| 11 | 24 | 33 | 25 | 29 | 26 | 24 | 19 | 19 | 26 | 26 | 24 | 32 | 25 |
| 13 | 31 | 31 | 38 | 38 | 37 | 36 | 30 | 27 | 35 | 39 | 34 | 40 | 34 |
| 16 | 61 | 63 | 75 | 76 | 55 | 56 | 50 | 42 | 51 | 54 | 45 | 47 | 58 |
| 17 | 32 | 34 | 40 | 39 | 36 | 33 | 26 | 22 | 33 | 32 | 25 | 30 | 33 |
| 19 | 34 | 37 | 41 | 40 | 31 | 30 | 25 | 22 | 31 | 31 | 25 | 30 | 32 |
| 20 | 16 | 19 | 19 | 23 | 18 | 19 | 12 | 12 | 18 | 16 | 12 | 19 | 17 |
| 21 | ** | 20 | 21 | 26 | 20 | 20 | 14 | 13 | 20 | 18 | 13 | 20 | 17 |
| 23 | 16 | 18 | 19 | 23 | 18 | 19 | 12 | 12 | 18 | 16 | 12 | 19 | 17 |
| 25 | 17 | 18 | 20 | 26 | 21 | 21 | 14 | 16 | 20 | 20 | 13 | 20 | 19 |
| 28 | 68 | 71 | 82 | 78 | 79 | 79 | 77 | 66 | 78 | 83 | 72 | 72 | 76 |
| 29 | 22 | 24 | 31 | 33 | 34 | 32 | 24 | 23 | 34 | 31 | 25 | 30 | 29 |
| 31 | 22 | 25 | 30 | 33 | 33 | 30 | 23 | 23 | 33 | 30 | 26 | 31 | 28 |
| 32 | 13 | 15 | 17 | 22 | 20 | 19 | 13 | 13 | 21 | 18 | 14 | 20 | 17 |
| 33 | 20 | 31 | 63 | 75 | 70 | 68 | 16 | 16 | 24 | 21 | 18 | 25 | 41 |
| 35 | 18 | 22 | 21 | 26 | 24 | 23 | 16 | 16 | 24 | 22 | 19 | 25 | 21 |
| 37 | 19 | 19 | 23 | 27 | 26 | 24 | 18 | 18 | 25 | 23 | 19 | 26 | 22 |

# TABLE A-10. RANGE BETWEEN MEAN MAXIMUM AND MEAN MINIMUM (°F)

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP* | OCT | NOV | DEC | YEARLY MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22 | 31 | 30 | 31 | 30 | 36 | 34 | 29 | 29 | 37 | 36 | 32 | 31 |
| 2 | 20 | 28 | 28 | 29 | 28 | 33 | 31 | 26 | 27 | 34 | 32 | 29 | 29 |
| 4 | 43 | 59 | 56 | 57 | 57 | 62 | 58 | 55 | 54 | 60 | 56 | 50 | 56 |
| 5 | 13 | 17 | 16 | 16 | 15 | 16 | 15 | 14 | 15 | 18 | 17 | 15 | 16 |
| 7 | 7 | 9 | 9 | 9 | 8 | 9 | 8 | 8 | 8 | 10 | 9 | 8 | 9 |
| 8 | 5 | 7 | 6 | 6 | 5 | 6 | 6 | 5 | 6 | 7 | 7 | 6 | 6 |
| 9 | 5 | 5 | 4 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| 11 | 9 | 11 | 9 | 9 | 7 | 8 | 7 | 7 | 8 | 11 | 11 | 10 | 9 |
| 13 | 15 | 19 | 17 | 17 | 15 | 16 | 15 | 15 | 16 | 20 | 20 | 18 | 17 |
| 16 | 36 | 48 | 46 | 48 | 33 | 36 | 33 | 30 | 29 | 33 | 32 | 28 | 36 |
| 17 | 15 | 20 | 18 | 18 | 13 | 14 | 12 | 11 | 11 | 14 | 13 | 12 | 14 |
| 19 | 17 | 23 | 20 | 20 | 12 | 14 | 13 | 12 | 12 | 15 | 14 | 12 | 15 |
| 20 | 5 | 7 | 6 | 5 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 4 |
| 21 | ** | 8 | 7 | 7 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 5 |
| 23 | 5 | 7 | 6 | 6 | 3 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| 25 | 6 | 8 | 7 | 7 | 6 | 6 | 5 | 5 | 5 | 6 | 6 | 5 | 6 |
| 28 | 40 | 54 | 51 | 52 | 51 | 56 | 53 | 50 | 50 | 57 | 54 | 48 | 51 |
| 29 | 9 | 11 | 11 | 11 | 10 | 12 | 12 | 11 | 11 | 13 | 12 | 10 | 11 |
| 31 | 9 | 12 | 13 | 11 | 11 | 12 | 12 | 11 | 11 | 13 | 12 | 11 | 12 |
| 32 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 3 |
| 33 | 6 | 8 | 17 | 42 | 44 | 37 | 6 | 6 | 6 | 7 | 7 | 6 | 16 |
| 35 | 6 | 8 | 8 | 7 | 6 | 6 | 6 | 6 | 6 | 8 | 8 | 7 | 7 |
| 37 | 6 | 8 | 9 | 7 | 4 | 7 | 6 | 6 | 6 | 8 | 8 | 7 | 7 |

* incomplete data day 262   ** significant data lost

# APPENDIX B

**TABLE B-1.**     MEAN TEMPERATURES (°F) 1994

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 54 | 57 | 68 | 74 | 81 | 94 | 96 | 97 | 90 | 74 | 58 | 53 | 75 |
| 2 | 55 | 57 | 68 | 74 | 81 | 94 | 96 | 97 | 90 | 74 | 58 | 53 | 75 |
| 4 | 61 | 63 | 76 | 83 | 92 | 105 | 107 | 108 | 99 | 81 | 63 | 57 | 83 |
| 5 | 62 | 63 | 75 | 81 | 88 | 101 | 103 | 105 | 98 | 81 | 64 | 58 | 82 |
| 7 | 65 | 65 | 77 | 83 | 88 | 102 | 104 | 106 | 100 | 84 | 66 | 60 | 83 |
| 8 | 65 | 65 | 77 | 82 | 86 | 100 | 103 | 105 | 99 | 84 | 67 | 60 | 83 |
| 9 | 66 | 66 | 78 | 83 | 87 | 101 | 104 | 107 | 101 | 86 | 68 | 63 | 84 |
| 11 | 69 | 68 | 80 | 85 | 89 | 103 | 105 | 108 | 102 | 88 | 71 | 63 | 86 |
| 13 | 67 | 68 | 80 | 85 | 90 | 104 | 105 | 108 | 102 | 87 | 69 | 62 | 86 |
| 16 | 60 | 62 | 75 | 82 | 90 | 103 | 105 | 106 | 98 | 80 | 63 | 57 | 82 |
| 17 | 62 | 63 | 75 | 80 | 86 | 99 | 102 | 104 | 97 | 81 | 64 | 58 | 81 |
| 19 | 64 | 64 | 76 | 82 | 88 | 101 | 104 | 106 | 99 | 84 | 66 | 60 | 83 |
| 20 | 65 | 65 | 76 | 82 | 85 | 99 | 103 | 106 | 100 | 86 | 68 | 61 | 83 |
| 21 | 69 | 68 | 78 | * | * | 100 | 103 | 106 | 101 | 87 | 70 | 63 | 70 |
| 23 | 67 | 66 | 77 | 82 | 85 | 98 | 102 | 105 | 100 | 86 | 69 | 62 | 83 |
| 25 | 66 | 66 | 78 | 85 | 89 | 102 | 105 | 107 | 101 | 87 | 69 | 62 | 85 |
| 28 | 61 | 63 | 75 | 82 | 90 | 103 | 104 | 106 | 97 | 80 | 63 | 57 | 82 |
| 29 | 62 | 63 | 75 | 81 | 87 | 100 | 103 | 105 | 97 | 81 | 64 | 58 | 81 |
| 31 | 63 | 64 | 76 | 82 | 87 | 101 | 103 | 105 | 99 | 83 | 65 | 59 | 82 |
| 32 | 63 | 63 | 75 | 81 | 86 | 100 | 103 | 105 | 99 | 84 | 66 | 59 | 82 |
| 33 | 64 | 65 | 75 | 81 | 85 | 99 | 102 | 104 | 98 | 83 | 66 | 59 | 82 |
| 35 | 63 | 63 | 74 | 80 | 84 | 98 | 101 | 104 | 97 | 83 | 66 | 59 | 81 |
| 37 | 64 | 64 | 76 | 82 | 86 | 100 | 102 | 105 | 99 | 84 | 66 | 60 | 82 |

**TABLE B-2.**     TEMPERATURE STANDARD DEVIATIONS (°F) 1994

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY S.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 11 | 12 | 14 | 13 | 13 | 12 | 10 | 12 | 12 | 12 | 10 | 12 |
| 2 | 11 | 10 | 11 | 13 | 12 | 12 | 11 | 9 | 11 | 11 | 11 | 9 | 11 |
| 4 | 19 | 19 | 21 | 22 | 22 | 22 | 21 | 19 | 21 | 19 | 18 | 16 | 20 |
| 5 | 6 | 7 | 7 | 9 | 7 | 7 | 6 | 5 | 7 | 7 | 8 | 5 | 7 |
| 7 | 5 | 5 | 5 | 8 | 6 | 5 | 5 | 4 | 6 | 6 | 7 | 4 | 5 |
| 8 | 4 | 4 | 4 | 7 | 5 | 5 | 4 | 3 | 5 | 5 | 7 | 3 | 5 |
| 9 | 3 | 3 | 3 | 5 | 4 | 4 | 3 | 2 | 4 | 5 | 6 | 7 | 4 |
| 11 | 5 | 5 | 5 | 7 | 5 | 5 | 4 | 3 | 5 | 6 | 7 | 5 | 5 |
| 13 | 7 | 7 | 7 | 9 | 7 | 7 | 7 | 6 | 7 | 8 | 8 | 7 | 7 |
| 16 | 17 | 16 | 18 | 19 | 19 | 18 | 17 | 16 | 17 | 17 | 16 | 14 | 17 |
| 17 | 8 | 8 | 8 | 9 | 8 | 7 | 6 | 6 | 7 | 8 | 9 | 6 | 7 |
| 19 | 8 | 8 | 8 | 9 | 8 | 8 | 7 | 7 | 8 | 9 | 9 | 7 | 8 |
| 20 | 3 | 4 | 3 | 5 | 4 | 4 | 3 | 2 | 4 | 5 | 7 | 3 | 4 |
| 21 | 4 | 5 | 4 | * | * | 4 | 4 | 3 | 4 | 5 | 7 | 4 | 4 |
| 23 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | 2 | 4 | 5 | 6 | 3 | 4 |
| 25 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 3 | 5 | 5 | 6 | 3 | 4 |
| 28 | 19 | 18 | 20 | 20 | 20 | 20 | 19 | 18 | 19 | 18 | 17 | 15 | 19 |
| 29 | 5 | 6 | 6 | 8 | 6 | 6 | 6 | 5 | 6 | 6 | 7 | 4 | 6 |
| 31 | 5 | 5 | 5 | 8 | 6 | 6 | 5 | 5 | 6 | 6 | 7 | 4 | 6 |
| 32 | 3 | 3 | 3 | 6 | 4 | 4 | 3 | 2 | 4 | 5 | 6 | 2 | 4 |
| 33 | 4 | 4 | 5 | 6 | 5 | 6 | 14 | 7 | 5 | 5 | 6 | 4 | 6 |
| 35 | 4 | 4 | 4 | 6 | 5 | 5 | 4 | 3 | 5 | 5 | 6 | 3 | 4 |
| 37 | 4 | 4 | 4 | 6 | 5 | 5 | 4 | 3 | 5 | 5 | 6 | 4 | 5 |

* missing large number of data points

**TABLE B-3.**  **ABSOLUTE MAXIMUM TEMPERATURES (°F) 1994**

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY MEAN ABSOLUTE MAXIMUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 83 | 84 | 96 | 106 | 110 | 120 | 116 | 118 | 115 | 103 | 89 | 79 | 102 |
| 2 | 81 | 82 | 95 | 104 | 109 | 120 | 116 | 117 | 113 | 101 | 88 | 76 | 100 |
| 4 | 112 | 120 | 129 | 137 | 143 | 145 | 151 | 148 | 147 | 135 | 120 | 106 | 133 |
| 5 | 79 | 81 | 93 | 104 | 107 | 117 | 116 | 117 | 116 | 102 | 85 | 74 | 99 |
| 7 | 76 | 78 | 89 | 100 | 123 | 114 | 112 | 114 | 112 | 100 | 83 | 71 | 98 |
| 8 | 74 | 76 | 85 | 96 | 99 | 111 | 109 | 111 | 110 | 98 | 82 | 68 | 93 |
| 9 | 93 | 74 | 89 | 94 | 123 | 109 | 109 | 119 | 130 | 97 | 80 | 113 | 103 |
| 11 | 83 | 82 | 91 | 101 | 102 | 114 | 112 | 114 | 114 | 104 | 90 | 77 | 99 |
| 13 | 86 | 86 | 97 | 107 | 108 | 120 | 118 | 119 | 120 | 108 | 94 | 83 | 104 |
| 16 | 103 | 110 | 124 | 130 | 134 | 137 | 144 | 141 | 141 | 128 | 110 | 100 | 125 |
| 17 | 84 | 84 | 94 | 103 | 105 | 116 | 114 | 116 | 116 | 104 | 90 | 79 | 100 |
| 19 | 88 | 89 | 98 | 107 | 109 | 119 | 119 | 121 | 121 | 111 | 95 | 83 | 105 |
| 20 | 76 | 75 | 84 | 94 | 97 | 108 | 108 | 110 | 109 | 100 | 83 | 70 | 93 |
| 21 | 80 | 79 | 87 | * | * | 110 | 109 | 111 | 111 | 101 | 87 | 75 | 79 |
| 23 | 77 | 77 | 85 | 94 | 96 | 108 | 107 | 109 | 109 | 99 | 84 | 72 | 93 |
| 25 | 75 | 77 | 87 | 97 | 101 | 113 | 112 | 112 | 112 | 101 | 83 | 71 | 95 |
| 28 | 109 | 114 | 124 | 132 | 136 | 139 | 145 | 143 | 142 | 130 | 117 | 104 | 128 |
| 29 | 74 | 76 | 89 | 99 | 103 | 114 | 113 | 114 | 112 | 98 | 81 | 68 | 95 |
| 31 | 75 | 78 | 89 | 100 | 103 | 115 | 113 | 114 | 113 | 101 | 83 | 71 | 96 |
| 32 | 69 | 71 | 81 | 93 | 96 | 108 | 107 | 109 | 107 | 95 | 78 | 65 | 90 |
| 33 | 73 | 87 | 99 | 116 | 97 | 133 | 148 | 136 | 119 | 110 | 81 | 78 | 106 |
| 35 | 72 | 74 | 83 | 93 | 96 | 108 | 107 | 109 | 108 | 97 | 80 | 68 | 91 |
| 37 | 73 | 76 | 86 | 96 | 99 | 112 | 109 | 111 | 110 | 98 | 81 | 69 | 93 |

**TABLE B-4.**  **ABSOLUTE MINIMUM TEMPERATURES (°F) 1994**

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEARLY MEAN ABSOLUTE MINIMUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 31 | 33 | 45 | 44 | 54 | 65 | 70 | 76 | 60 | 48 | 29 | 31 | 49 |
| 2 | 33 | 34 | 46 | 47 | 58 | 68 | 72 | 77 | 62 | 48 | 30 | 32 | 50 |
| 4 | 36 | 36 | 48 | 49 | 59 | 70 | 74 | 80 | 65 | 49 | 32 | 33 | 53 |
| 5 | 48 | 47 | 58 | 61 | 72 | 87 | 85 | 89 | 80 | 63 | 45 | 44 | 65 |
| 7 | 55 | 53 | 63 | 67 | 77 | 92 | 89 | 94 | 86 | 70 | 52 | 50 | 71 |
| 8 | 57 | 55 | 66 | 69 | 78 | 92 | 90 | 95 | 87 | 73 | 55 | 52 | 72 |
| 9 | 60 | 58 | 70 | 75 | 78 | 95 | 94 | 100 | 89 | 63 | 59 | 55 | 75 |
| 11 | 60 | 57 | 68 | 72 | 80 | 94 | 92 | 98 | 90 | 76 | 57 | 48 | 74 |
| 13 | 54 | 52 | 63 | 67 | 76 | 89 | 87 | 92 | 84 | 69 | 52 | 49 | 70 |
| 16 | 38 | 38 | 50 | 52 | 61 | 71 | 77 | 82 | 69 | 53 | 36 | 36 | 55 |
| 17 | 48 | 47 | 58 | 61 | 70 | 84 | 85 | 89 | 79 | 63 | 45 | 43 | 64 |
| 19 | 50 | 49 | 61 | 64 | 72 | 85 | 88 | 91 | 83 | 66 | 49 | 46 | 67 |
| 20 | 58 | 57 | 68 | 72 | 77 | 91 | 93 | 99 | 91 | 76 | 57 | 54 | 75 |
| 21 | 61 | 58 | 68 | * | * | 92 | 92 | 98 | 90 | 76 | 59 | 54 | 62 |
| 23 | 60 | 58 | 69 | 73 | 78 | 90 | 93 | 99 | 91 | 77 | 59 | 55 | 75 |
| 25 | 58 | 57 | 69 | 74 | 80 | 93 | 93 | 97 | 90 | 76 | 58 | 54 | 75 |
| 28 | 36 | 36 | 48 | 50 | 59 | 70 | 73 | 79 | 65 | 52 | 34 | 35 | 53 |
| 29 | 50 | 49 | 60 | 63 | 73 | 88 | 86 | 90 | 82 | 67 | 48 | 46 | 67 |
| 31 | 52 | 51 | 62 | 66 | 75 | 88 | 88 | 92 | 84 | 69 | 51 | 48 | 69 |
| 32 | 57 | 56 | 68 | 73 | 78 | 93 | 92 | 98 | 90 | 76 | 57 | 54 | 74 |
| 33 | 56 | 54 | 52 | 69 | 77 | 85 | 73 | 82 | 82 | 73 | 54 | 51 | 67 |
| 35 | 55 | 54 | 64 | 69 | 76 | 89 | 90 | 95 | 86 | 73 | 54 | 51 | 71 |
| 37 | 55 | 54 | 64 | 69 | 78 | 91 | 88 | 94 | 86 | 73 | 54 | 51 | 71 |

* missing large number of data points

**TABLE B-5. RANGE FROM ABSOLUTE MAXIMUM TO ABSOLUTE MINIMUM TEMPERATURE (° F) 1994**

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | RANGE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 51 | 52 | 51 | 61 | 55 | 55 | 47 | 42 | 55 | 55 | 60 | 49 | 53 |
| 2 | 48 | 48 | 49 | 57 | 51 | 52 | 44 | 40 | 51 | 53 | 58 | 44 | 50 |
| 4 | 76 | 84 | 81 | 88 | 84 | 75 | 77 | 69 | 81 | 86 | 88 | 73 | 80 |
| 5 | 30 | 34 | 35 | 43 | 35 | 30 | 30 | 28 | 36 | 39 | 40 | 31 | 34 |
| 7 | 21 | 25 | 26 | 33 | 46 | 22 | 24 | 20 | 27 | 30 | 31 | 21 | 27 |
| 8 | 17 | 21 | 20 | 28 | 21 | 18 | 20 | 16 | 22 | 25 | 27 | 17 | 21 |
| 9 | 32 | 16 | 19 | 20 | 45 | 15 | 15 | 19 | 41 | 34 | 21 | 59 | 28 |
| 11 | 23 | 25 | 23 | 29 | 23 | 20 | 20 | 17 | 24 | 28 | 32 | 29 | 24 |
| 13 | 32 | 34 | 34 | 39 | 33 | 30 | 31 | 27 | 35 | 39 | 42 | 33 | 34 |
| 16 | 66 | 73 | 74 | 78 | 73 | 67 | 67 | 60 | 72 | 75 | 74 | 64 | 70 |
| 17 | 36 | 37 | 36 | 43 | 35 | 32 | 29 | 28 | 36 | 41 | 45 | 36 | 36 |
| 19 | 38 | 40 | 37 | 43 | 37 | 34 | 31 | 30 | 38 | 44 | 46 | 37 | 38 |
| 20 | 18 | 19 | 16 | 22 | 20 | 17 | 15 | 11 | 19 | 24 | 26 | 16 | 18 |
| 21 | 20 | 21 | 19 | * | * | 18 | 17 | 13 | 20 | 24 | 28 | 20 | 17 |
| 23 | 17 | 19 | 16 | 21 | 18 | 18 | 15 | 11 | 18 | 22 | 25 | 17 | 18 |
| 25 | 16 | 20 | 18 | 23 | 21 | 20 | 19 | 15 | 23 | 25 | 25 | 17 | 20 |
| 28 | 73 | 78 | 76 | 82 | 77 | 69 | 72 | 64 | 77 | 78 | 83 | 69 | 75 |
| 29 | 24 | 27 | 29 | 36 | 30 | 26 | 26 | 24 | 31 | 30 | 33 | 22 | 28 |
| 31 | 23 | 26 | 27 | 34 | 28 | 26 | 25 | 22 | 29 | 31 | 32 | 22 | 27 |
| 32 | 12 | 16 | 13 | 20 | 18 | 15 | 15 | 11 | 17 | 19 | 21 | 11 | 16 |
| 33 | 18 | 33 | 47 | 47 | 21 | 48 | 75 | 55 | 37 | 37 | 27 | 27 | 39 |
| 35 | 17 | 20 | 19 | 24 | 20 | 20 | 17 | 14 | 21 | 24 | 26 | 17 | 20 |
| 37 | 18 | 22 | 21 | 27 | 22 | 20 | 21 | 17 | 24 | 25 | 27 | 18 | 22 |

**TABLE B-6. NUMBER OF DATA POINTS 1994**

| CHANNEL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 2 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 4 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 5 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 7 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 8 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 9 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 11 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 13 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 16 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 17 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 19 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 20 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 21 | 744 | 672 | 744 | 261 | 486 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 23 | 744 | 672 | 744 | 712 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 25 | 744 | 672 | 744 | 712 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 28 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 29 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 31 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 32 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 33 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 35 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |
| 37 | 744 | 672 | 744 | 717 | 575 | 719 | 720 | 744 | 716 | 744 | 720 | 744 |

\* missing large number of data points